CORROSION CONTROL BY CATHODIC PROTECTION — THEORETICAL AND DESIGN CONCEPTS FOR MARINE APPLICATIONS*

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INTRODUCTION

On 22nd January, 1824, in London, the President of the British Royal Society, during the introduction of a paper on the corrosion of copper in sea water, advanced the hypothesis that—"chemical attractions may be exalted, modified or destroyed by changes in the electrical states of bodies; that substances will only combine when in different electrical states; and that by bringing a body naturally positive artificially into a negative state, its usual powers of combination are altogether destroyed. It was in reasoning upon this general hypothesis", he continued, "that I was led to the discovery which is the subject of this paper".

The speaker was Sir Humphry Davy and his discovery was cathodic protection. He made the discovery during investigations into the corrosion of copper sheathing on British ships of war, a project which he was conducting by request of the Navy Board. As a result of his discovery some successful use was made of iron and zinc blocks attached to the copper sheathing.

With the transition from wooden to steel hulled vessels in the mid 1800's, it became traditional to fit zinc slabs, or "protectors", as they were called, to the stern areas of steel vessels. Theoretically these zinc slabs provided local protection, particularly against the galvanic effects of the bronze propeller, but the impurity of the zinc used and lack of any scientific approach probably rendered the protection ineffective in many cases.

The next major step forward in the usage of cathodic protection was precipitated, not in the marine field, but on land, as a result of corrosion problems with buried pipelines. It took place in the early 1930's in the extensive networks of oil and gas pipelines installed in America where the leak frequency and subsequent losses were approaching intolerable levels. The cathodic protection of these pipelines was achieved by applying the same principles used by Davy, except that the protective potentials were often "impressed" using an independent conventional power source, instead of being obtained galvanically using "sacrificial" anodes.

Today cathodic protection is employed in many forms, some of which are very sophisticated, but by no means is this unique method of corrosion control exploited as fully as it could be. Besides combatting normal corrosion, cathodic protection can be employed to reduce dezincification and cavitation of copper based alloys, pitting and crevice corrosion of chromium/nickel steels and fatigue corrosion.

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THEORY

The theory of corrosion and cathodic protection as outlined by Davy, was not developed to any extent until a century later, in the 1920's, on the basis of work by U. R. Evans, and his colleagues at Cambridge.

The theory as it now stands, depicts corrosion as a definite and predictable electro-chemical process; and cathodic protection as a forced, directional modification of this process.

Galvanic Cell

One of the most basic elements of the corrosion reaction is the galvanic cell, which can be defined as a combination of two different electrodes immersed in an electrolyte, which converts chemical energy into electrical energy and produces corrosion as the by-product.

A simple analogy of a galvanic corrosion cell, which conveniently symbolizes the electrical relationships in the internal and external cell circuits, is the dry cell battery. Here the two electrodes are graphite and zinc. When the cell is in the short-circuited condition, as most galvanic corrosion cells are in practice, an electrical current flows between the two electrodes with corrosion of the zinc as the by-product. If an ammeter was connected across the electrodes it would be seen that conventional current flows in the external circuit from the carbon to the zinc. Then, in the internal circuit, by definition, the carbon electrode is called the cathode (because current enters the electrode from the electrolyte) and the zinc electrode is called the anode (because current flows from the electrode into the electrolyte). The corrosion of the zinc that occurs is directly proportional to the current that flows.

In practice, many types of corrosion cells, besides the galvanic type, are possible. The driving potentials of these cells can be produced by differentials in aeration, electrolyte concentration and temperature, and the cells may operate on a micro or macro scale. Macro cell action is often the most damaging because it can result in deep pitting.

Electro-Motive Force and e.m.f. Series

The tendency for a corrosion reaction to proceed is indicated by the difference in the free chemical energy between one electrode and its environment and the other electrode and its environment, which can in turn be related to e.m.f. and n for each electrode reaction, where e.m.f. is the electro-motive force and n is the number of electrons taking part in the reaction. The e.m.f. of a single metal electrode in a specific electrolyte can be calculated and one particular listing of these calculated e.m.f. values is known as the "e.m.f. series". The e.m.f. of a galvanic cell is equal to the algebraic sum of the e.m.f's of the two electrodes forming the cell.

Galvanic Series

A more practical innovation of the e.m.f. series is the "galvanic series" in which the metals and alloys are arranged in order according to their actual measured e.m.f. in a given environment. A galvanic series for some common metals in sea water is given below:

Magnesium — Anodic (active)
Zinc
Aluminium
Mild Steel
Lead/tin solder
Lead
Tin
Naval Brass
Red Brass
Copper
Cupro-nickel
Nickel
Monel
Stainless Steel (passive) — Cathodic (passive)

The galvanic series shows at a glance, which metal will be the anode (corroding electrode) and which will be the cathode of a galvanic cell. Note that steel is anodic and could be expected to suffer galvanic attack when coupled to any of the copper-based alloys commonly used in the marine field.

Polarization

If the theoretical cell action described, persisted unimpeded, corrosion would be a more serious problem than it is. Fortunately it does not. The reason for this is that the corrosion cell action tends to stifle or "polarize" itself. Polarization can occur at either or both electrodes and is dependent on the reactions and reactants at the electrodes. Polarization can be considered as an interposed e.m.f. in the corrosion cell circuit which always opposes the driving e.m.f. of the cell. It is by capitalizing on this polarization effect, that cathodic protection functions.

Equivalent Circuits and E-I Diagrams

The action of cathodic protection is to increase the polarization (increase the interposed e.m.f.) on the cathodic area until its potential equals the open circuit potential of the anodic area. In this way, the effective driving e.m.f. of the corrosion cell is reduced to zero and no corrosion current can flow. The mechanism can be explained in conjunction with the simplified equivalent circuit and *E-I* diagram in Figs 1 and 2.

The circuit in Fig. 1 can be analysed by the basic laws of electricity as follows:

at X, $$I_c = I_{cor} + I_{cp} \tag{1}$$

around the loop ACX

$$E_c - E_a = I_{cor} R_a + I_c R_c \tag{2}$$

substituting (1) in (2) —

$$E_c - E_a = I_{cor}(R_a + R_c) + I_{cp} R_c$$

or $$I_{cor} = \frac{(E_c - E_a) - I_{cp} R_c}{R_a + R_c} \tag{3}$$

or $$I_{cp} = \frac{(E_c - E_a) - I_{cor}(R_a + R_c)}{R_c} \tag{4}$$

From these equations it is seen that I_{cor} will be reduced to zero when the cathodic protection term $I_{cp} R_c$ is increased to equal the corrosion reaction term $(E_c - E_a)$. The cathodic protection current necessary to achieve this condition will then equal

$$\frac{(E_c - E_a)}{R_c}.$$

A very simple hydraulic analogy can be drawn to illustrate this mechanism. Consider two buckets of water side by side, one full and the other empty, and the two connected by a pipe. Water will flow from the bucket with the higher level to that with the lower level. If, however, the empty bucket is filled from another independent source, the water flow will stop, since the head of water in the empty bucket has been raised to equal the head of water in the full bucket. The initial water head differential is of course analogous to the corrosion cell e.m.f. or driving potential; and the water from the independent source analogous to the cathodic protection current.

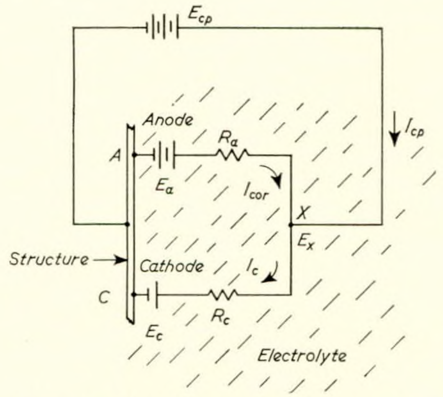

FIG. 1—*Simplified equivalent circuit*

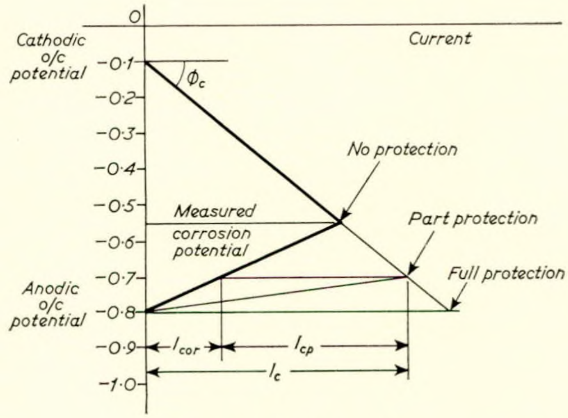

FIG. 2—*Polarization*

The simplified circuit in Fig. 1 is graphically depicted in the *E-I* diagram in Fig. 2. I_c, I_{cor} and I_{cp} are the currents and E_c and E_a the potentials shown in the circuit. The latter have been given arbitrary values. Also shown in the diagram is the slope of the cathodic polarization curve φ_c, equal to the electrode resistance E/I.

Using this diagram, the relationships in equations (1) to (4) can be demonstrated graphically, but of particular interest, is the value of the cathodic protection current required,

$$I_{cp} = \frac{E_c - E_a}{\varphi_c} \tag{5}$$

in which I_{cp} is seen to be dependent only on the difference in potential between anodic and cathodic areas and on the slope of the cathodic polarization curve.

Although somewhat over-simplified, these equations illustrate the relationships between the various electrical parameters and the main influencing factors.

Potential Criteria of Protection

Potentials of metals in electrolytes are measured using a high internal resistance voltmeter and a special electrode (half-cell), to make contact with the electrolyte. The voltage indicated by the meter is the difference in potential between the metal and the half-cell, and will vary in value and sign according to the type of half-cell employed. Using a silver/silver chloride half-cell, which is common in marine work, the potential of cathodically protected steel will be negative relative to the cell, e.g. −0·78 volts. Making the same measurement with a pure zinc half-cell, on the other hand, the potential would be positive relative to the cell, e.g. +0·250. Increased cathodic protection in the above example would increase the value of the silver/silver chloride reading and decrease the value of the zinc cell reading. In either case the potential of the protected metal is made more negative.

The minimum potential for complete cathodic protection (i.e. potential of anodic areas to which the cathodic areas must be raised) will vary depending on the metal being protected, the electrolyte and the type of corrosion cell action being combatted. The following are the approximate accepted levels relative to a Ag/AgCl half-cell:

Steel	−0·78 V	
	−0·9 V to −1·0 V	anaerobic bacteria present
Lead	−0·65 V	variable
Aluminium	−0·78 V	variable.
Galvanizing	−0·95 V	

Below these levels, only partial protection will be obtained proportional to the amount the potential is moved in the negative direction, or the "potential swing" imposed. Above these levels the excess protective current will be wasted.

DESIGN

Cathodic protection can be applied by one of two methods—"sacrificial anode" protection in which the current is provided by galvanic action, or "impressed current" which employs an outside electrical power source of a more conventional type.

Both methods are equally effective within their own limitations and are designed using the same basic procedure. Choice of method is therefore determined by operational and economic considerations.

The most difficult exercise in the basic design procedure is to accurately estimate the current required. Once this parameter has been established, the remainder of the design to determine the circuit resistance and the driving voltage required amounts to fairly basic electrical engineering. The three parameters, current, circuit resistance and voltage, are related by Ohms Law and once any two are known, the third can be simply calculated.

Current Requirements

For bare steel in a marine environment the current required for protection is influenced by:

1) properties of the water such as resistivity/salinity, temperature, velocity and depth;
2) degree of polarization, which in sea water is primarily determined by build-up of calcareous deposits on the protected surface;
3) condition of any applied organic coatings.

Current requirements vary considerably, not only from installation to installation, but from area to area within the same installation, and can only be estimated from previous experience. The following figures indicate the order of requirements for bare steel in sea water.

	Current density (mA/ft^2)
after prepolarization treatment	3–5
without prepolarization treatment	6–9
in moving water or structure moving	6–18
in mud below water	1½

Applied organic coatings can decrease the current required by a factor of 5 to 100, according to their type and condition, mainly by reducing the area of bare steel exposed.

Circuit Resistance

The second design parameter, circuit resistance, consists mainly of the anode/electrolyte component which is determined by water resistivity and size, shape and number of anodes.

Calculation of anode resistance by a purely theorectical approach is mathematically possible but complex for all but the simplest shapes. Appropriate empirical formulae are often more convenient for this task. The following formulae apply for anodes immersed in an electrolyte of resistivity ρ. R is the resistance to a remote cathode.

Hemisphere radius "a"	$R = 0{\cdot}16\dfrac{\rho}{a}$
Vertical rod radius "a", inserted distance L through surface of electrolyte (Dwight's equation)	$R = \dfrac{\rho}{2\pi L}\left(\ln\dfrac{4L}{a} - 1\right)$
Any shape (approximation based on area)	$R = \dfrac{{\cdot}315\rho}{\sqrt{A}}$

Dwight's equation can be modified in a number of ways to determine the resistance of most practical anode shapes.

Where anodes are arranged close together, their effective resistance is increased by what is known as an "interference factor". If this factor is close to unity as is often the case, the total resistance of n identical anodes approximates $1/n$ times the resistance of one anode. Total circuit resistance will include, in addition, the ohmic resistance of the structure and any conductors which complete the circuit.

Driving Voltage

Having established the current requirements and circuit resistance, the third parameter, driving voltage, is determined from the other two by Ohm's Law. Alternatively, the driving voltage may be selected first and a specific circuit resistance set as a target for the anode design. This latter procedure must be followed for sacrificial protection design since the voltage available is pre-fixed for any given sacrificial anode material. Driving voltages for impressed current protection, on the other hand, are generally unrestricted.

Sacrificial Anode Design

Anode Materials

The materials used for sacrificial anodes are magnesium, zinc and aluminium alloys. Typical properties of these alloys are summarized in Table I.

Selection of anode material is based primarily on driving voltage requirements then on cost of protection. Magnesium being the most expensive, is normally only employed where its high driving potential is warranted, such as in higher resistivity estuarine waters or where only a short life is necessary. Otherwise the choice is between aluminium and zinc of which aluminium is currently the cheapest. For shipping other factors to be considered are weight, volume and anti-fouling tendency.

TABLE I

Material	Driving Voltage (Rel. Ag/AgCl)	Current Output (Amp H/lb)	Consumption (lb/Amp yr)	Density (lb/in^3)
Magnesium alloys (various)	1·5–1·65	500	17·5	0·063
Zinc alloy	1·05	350	24·5	0·258
Aluminium alloys (various)	1·0–1·13	700–1280	12–6·8	0·107

Anode Dimensions and Numbers

Once the anode metal has been selected, the size, shape and number of anodes are designed to satisfy the predetermined current and life requirements. For a maximum life, a minimal number of large and compact anodes will be required to give a maximum volume of sacrificial metal. For a short-life system the anodes will be more numerous and smaller in cross-section and total volume. In either case, for the same installation, the total circuit resistance will be approximately the same. As the anodes are consumed, they will be reduced in size and output. Hence if full protection is to be maintained to the end of the design life of the system, the circuit resistance must be computed on an appropriate end-point rather than the initial size and shape. A reasonable end-point is when the anodes are 75 per cent depleted, at which point their resistance may be approximately $1\frac{1}{2}$ times greater than initially. It follows that the initial output of the anodes will be more than is required, but this surplus is usefully employed in polarizing the protected structure.

Commercially available anode sizes and shapes will generally satisfy most design requirements, but for large projects, specially cast anodes may be warranted.

Impressed Current Protection

Impressed current systems are not limited by a fixed driving potential as sacrificial anode systems are, and can therefore be applied, in one way or another, to satisfy almost any performance requirement. Either the anode system can be designed for a preselected driving voltage, or the driving voltage selected for a preselected anode arrangement.

Anodes

Impressed current anodes are selected primarily for their electrical permanency and physical properties. The higher output anodes of recent development are extensively used, but where the cost of electrical power or the resistivity of the water is high, the economic advantage of the lower output anodes will be considerable. This is because of their lower anode-to-electrolyte resistance. Typical maximum current outputs and the relative driving voltages and power consumptions for various anodes at these outputs, are listed below. Normal operating current outputs are of course normally less than the maximums quoted.

TABLE II

Anode Type	Maximum Current Output Amps/ft^2	Relative Driving Voltage/Power Consumed
* Graphite	0·5	Unity
* Silicon Iron	3	2·5
† Lead/Silver Alloy	50+	10
† Platinized titanium	100	14
† Lead/Platinum bi-electrode	150	17

(* referred to as "low output" anodes)
(† referred to as "high output" anodes)

It can be seen from the relative power consumptions listed in Table II that any operational or performance advantages gained with high output anodes should be weighed carefully against their higher running costs. Other aspects to consider, particularly with platinized titanium anodes, include sensitivity to excessive applied voltage and a.c. ripple.

Spread of Protection

Spread of protection is influenced by the anode arrangement used, the proximity of the anodes to the protected structure, the driving voltage applied and in some cases the ohmic resistance of the protected structure. A uniform spread of protective potentials will normally require a uniform current density on the protected surface, but since this is difficult to achieve in practice some overprotection is often unavoidable. The spread of protection on a structure in a marine environment can generally be satisfactorily evaluated by theoretical calculations. Where this is not possible, trials on the structure itself or a model study can be employed.

On large structures, a reasonably uniform current density can be obtained by distributing a number of small independent systems, or at least distributing the anodes. However, on long structures such as submarine pipelines, this procedure is generally impracticable and some degree of overprotection must be tolerated.

On structures where anodes are directly attached, i.e. ships' hulls, it is often necessary to limit overprotection by shielding the protected surface immediately adjacent to the anode. The distance the shield needs to extend from the edge of the anode depends upon the driving voltage applied, and can be calculated.

Although overprotection does not reduce the pure protective function of a system, it can produce harmful secondary effects such as coating damage, hydrogen embrittlement and alkaline attack of aluminium or lead. The degree of over-protection allowable will therefore vary depending on the likelihood of these secondary effects.

Power Sources

The most convenient and commonly used source of electrical power is a single or 3 phase a.c. supply main. The a.c mains voltage is reduced to the required level and made adjustable by means of a tapped transformer, then rectified to d.c. using selenium or silicon diode rectifiers. Transformer rectifier units are commercially available in sizes and types to meet most practical requirements.

Other less common power sources are d.c. mains (on ships), d.c. generators driven by Diesel motors, wind-driven generators with batteries and thermo-electric generators, powered by gas. With the recent expansions in natural gas utilization, there has been an increased use of thermo-generators which are now available in several sizes off the shelf. On natural gas lines these units are economically competitive with transformer rectifiers, and even using bottled gas the cost of operation at 17c. per kW h may not be prohibitive where other sources of power are unavailable.

Future sources of power may include fuel, atomic, and solar cells, but at present these are too impractical due primarily to their high initial cost.

Automation

Automation is the theme of today and this applies equally to impressed current cathodic protection. The aim is to eliminate the necessity for manual control and avoid under or overprotection. In systems where the current demands fluctuate appreciably, automation is practically a necessity, but in other cases it may only be an expensive convenience.

Earlier automatic systems employed mechanical servodrive regulating auto-transformers to control the output voltage. Such systems are now superseded by magnetic and transistor amplifiers, saturable reactors and silicon controlled rectifiers. Another recent development is the constant current rectifier.

Interference Corrosion

If cathodic protection currents flowing through the water can find a lower resistance conducting medium, such as a steel pipe, they will enter, flow along, then leave the pipe. In such an example the pipe would be corroded at the point of current departure. Interference corrosion is normally serious because it is often concentrated and may continue undiscovered until failure or perforation has occurred. The likely existence of any foreign structures or pipes should be investigated at the design stage.

Coating Destruction

Most coating systems except the very thick coal-tar enamel types, will break down if subjected to potentials much greater than one volt for long periods. Such potentials are often attained with impressed current systems, particularly where high output anodes are employed. Again the effect should be considered at the design stage and preferably the cathodic protection and coating systems designed hand-in-hand.

Hydrogen Embrittlement

Hydrogen may be produced on cathodically protected structures raised above the "hydrogen overvoltage" potential. Precautions must therefore be taken to adequately control protective potentials on any high tensile steels sensitive to hydrogen embrittlement—an obvious application for automatic voltage control.

Reaction Products

Reaction at the anodes of an impressed current system or on the surface of the protected metal can release unwanted by-products. Examples are the breakdown products of anodes which may contaminate drinking water, the release of chlorine in closed salt water tanks and increased alkalinity on protected lead or aluminium which can lead to destruction rather than protection, of these metals.

Fire Hazard

Unless properly designed and operated, cathodic protection schemes can incur an explosion or fire hazard in areas where inflammable materials or liquids are handled. This hazard may be direct, as from a malfunction of inadequately explosion-proofed equipment, or indirect as from inadequate bonding between a ship and wharf structure.

SUMMARY

Following its discovery by Davy, cathodic protection was slow to develop until its implementation on land, relatively recently, for the protection of buried pipelines. Since then, developments have been many, and applications on land and at sea are increasing rapidly, but full utilization of this unique process will remain retarded until the principles of its operation and application are more widely understood.

Since cathodic protection can be defined as a "forced, directional modification of the corrosion process", a good knowledge of the corrosion process is a pre-requisite. Of particular importance is the e.m.f. (electrical driving force) of the corrosion cell and polarization (in effect, the electrical retarding force) which always opposes the e.m.f. and is always present to a greater or lesser extent. It is where self-polarization is present to a lesser degree that the most severe corrosion occurs; and the action of increasing polarization by means of cathodic protection becomes a most effective method of corrosion control.

Cathodic protection design mainly amounts to straightforward electrical engineering. The most difficult exercise is the estimation of current requirements which generally must be based on long experience. Obtaining an economical life from impressed current "permanent" anodes is less of a problem following the developments of the versatile platinized titanium and lead alloy anodes. Advances in aluminium alloy sacrificial anodes throw a new light on this method of protection in marine environments.

The design procedure outlined is a simple solution of Ohm's Law—having estimated I, find a suitable combination of E and R. With sacrificial anodes E is limited to a specific value according to the alloy used. With impressed current the design is more involved but nevertheless the same basic procedure holds.

While cathodic protection is relatively simple to apply for appreciable gains, there are traps for the unwary and his neighbour. Effects such as interference corrosion, coating destruction and hydrogen embrittlement can be catastrophic unless eliminated at the design stage. Technical difficulties or economic considerations, however, will rarely exclude cathodic protection, either solely or in conjunction with coatings, as a totally effective method of corrosion control where this degree of corrosion control is warranted.

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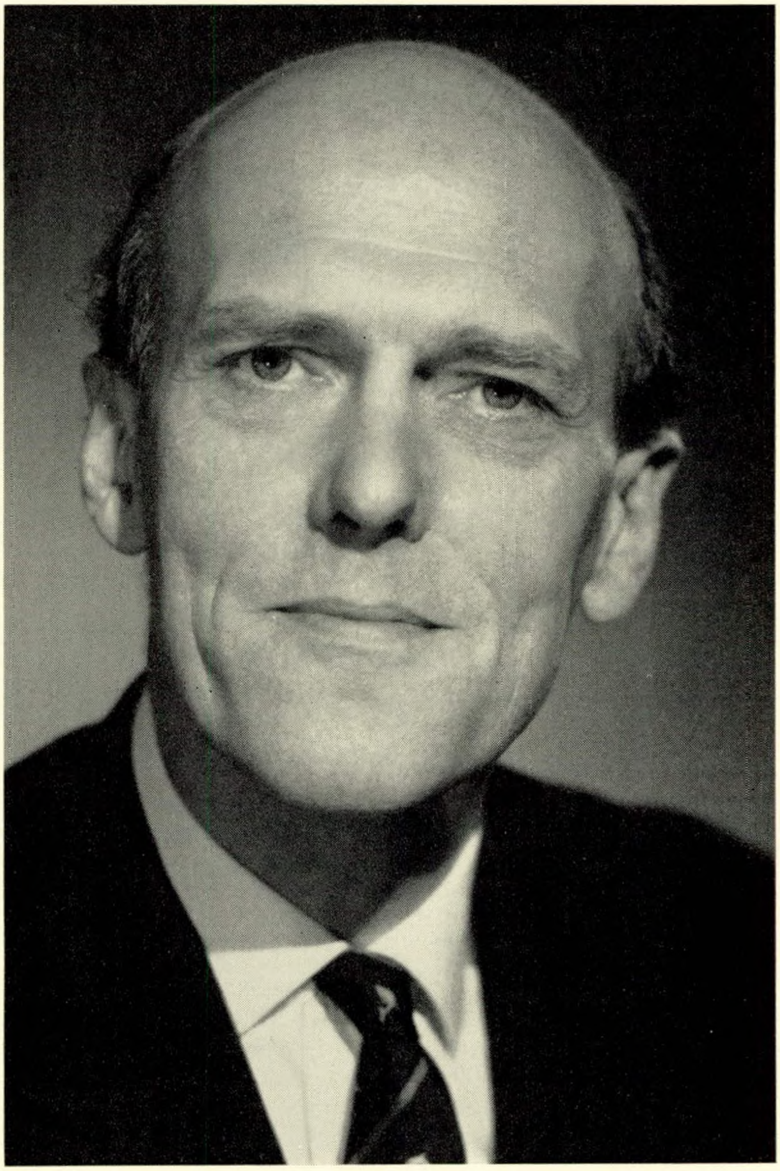

MICHAEL A. SINCLAIR SCOTT, C.B.E.

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Mr. Sinclair Scott, chairman of the Scott Lithgow Group, was born in Ayrshire in 1917. He is the younger son of the late Cedric Cuningham Sinclair Scott and Selina Amelia Alexander, second daughter of the late Lieutenant-Colonel H. G. S. Alexander of Carrickmore, Co. Tyrone. He is the seventh generation to be actively engaged in his family's 260-year old shipbuilding business, which he joined on leaving Fettes College in 1935.

He started his working life as an apprentice engineer and gained experience in many departments of the company before being appointed to its head office, after the war, as assistant to the managing director. Appropriately, he saw war service as an officer in the Royal Navy. In 1940 his ship was torpedoed and sunk in the North Sea and later he served in destroyers in the Western Approaches of the North Atlantic, the Mediterranean, and on Russian convoy duties. In 1942 he married the younger daughter of the late Henry H. Stanislaus of Wellesley Hills, Massachusetts.

In 1950 he was appointed a director of the family business, Scotts' Shipbuilding and Engineering Co. Ltd. Four years later he became deputy managing director and on 1st January 1957, he was appointed chairman.

Since then he has served on a great number of bodies, both local and national, mostly in connexion with shipbuilding interests. He was appointed in 1957 to the executive board of the Shipbuilding Conference and became Vice-President in 1963. Two years later he was appointed President, a position he held until the Conference was re-formed as the Shipbuilders' and Repairers' National Association in 1967. He became first President of the new combined body which embraces the interests of the Shipbuilding Conference, the Shipbuilding Employers' Federation and the Dry Dock Owners and Repairers Central Council.

He was appointed a Commander of the Order of the British Empire by Her Majesty The Queen in January 1966.

Among his many other activities during the last decade, he has served as a member of the General Committee of Lloyd's Register of Shipping (and of the Scottish Committee); Chairman of the Warship Group of the Shipbuilding Conference; member of the Council of the Confederation of British Industry; trustee of the Clyde Lighthouses; director of the Firth of Clyde Dry Dock Co. Ltd.; trustee of Sir Gabriel Wood's Mariners' Home; Chairman of Greenock Provident Bank and Chairman of Greenock Chamber of Commerce.

Many of these functions he relinquished before taking over as chairman of the Scott Lithgow Group formed by the merging of Scotts' Shipbuilding and Engineering Co. Ltd. and Lithgows Ltd. in 1967.

Mr. Sinclair Scott lives with his wife, and their son and daughter, at Skelmorlie, Ayrshire.

PRESIDENTIAL ADDRESS

of

MICHAEL A. SINCLAIR SCOTT, C.B.E.

I count it a very high privilege to have been elected President of this great Institute and to have the honour of addressing you this afternoon in that capacity.

For most of my life I have had the good fortune to be closely involved with both shipbuilding and marine engine building and to have developed an awareness of the relationship between the two and of their complementary, and often overlapping, areas of interest. Equally I have found that in being thus placed in close proximity to engineers of varying levels and attainments I have been able to formulate certain views on the profession and its place in the general pattern of current industrial development. For while I agree in essence with the opinion of an eminent predecessor in this office that change is not the prerogative of the present, I do believe that the hastening tempo of life, and particularly the growing sophistication of equipment and methods, demand that we must all be quicker on our feet today than at any time in our history. That is logical and inevitable.

Pressure of circumstance upon the people who build and engine ships is perhaps only equalled by that exerted on the shipping industry itself. The evolving pattern of world shipping is constantly throwing up new sets of parameters within which its engineers and suppliers must function. And if this is true of the shipping industry it is fair to conclude, I think, that it is common to many. In a manufacturing economy such as ours the rôle of the engineer must in this situation assume a growing importance. There is no doubt in my mind that members of this Institute and their colleagues in other sectors of engineering are fully conscious of the new challenges which are being presented daily, many of them problems which precedent cannot help to resolve and which may derive from the demands of new markets or materials, or simply from the ever-present need to maintain or enhance the quality and reliability of a product while pegging, or even cutting, its manufacturing cost. Experience in my own industry has shown that specified performance is now almost invariably more exacting.

Quality is, of course, a characteristic of performance rather than a definable ingredient. It is an old engineering maxim that you cannot inspect quality into a product—it has to be there. Engineering quality today is no longer something that is confined to pride, justifiable though it may be, in working tolerances. Nor should it be judged solely by the reading on a micrometer or a slide rule. Quality today must not only be present in design and in manufacture: it must also be manifest in a broad appreciation of product purpose and its market acceptability in relation to competing equivalents.

In our shipbuilding activities, we are, for the most part, assemblers of bought-in equipment. We are at the receiving end of a vast range of components which we build into end products whose cost to the customers is usually calculated in millions of pounds rather than thousands. The market, however, is keen and any lack of quality and reliability in the equipment we purchase can have serious repercussions indeed. Equally, the cost-effectiveness of the equipment must be realistic since in most cases competition is strong and price/performance factors are of the utmost importance.

I have been impressed over recent years by the activities of certain engineering concerns in the field of value analysis where a deliberate effort has been made to divest products of costly superfluities whose absence would not in any way vitiate performance. Probably the reverse. What I found significant was that in most instances where great progress was made by close analysis of the product in relation to its function, no formalized or deliberate effort of the kind had been made previously. It is, I suppose, quite understandable that human beings who have been following successfully a chosen and hitherto satisfactory path, sometimes over generations, do not seek to question the rightness of it all. Yet the fact remains that the appearance of a single new material or process could require the re-thinking of an entire design and manufacturing programme which had so far been thoroughly sound.

Engineers are sometimes regarded—and, I fear, sometimes regard themselves—as a race apart. It is so easy for a technologist, or a technician, to stay in the backroom isolated from the bustle of the business end of things. This may be acceptable where he is operating in a non-commercial context or in a field where competition is not a serious market factor; in such circumstances he may allow himself the luxury of being introspective.

There are, of course, at least two sides to every situation and I fully accept the submission that many organizations today may not positively encourage an emergence of their technical forces into the front line. But this is changing and more and more engineers are being involved at all stages of the production and selling processes—from research and development, design and value analysis to marketing, consumer acceptability and after-sales service. In my own organization the changing emphasis in engineering is best epitomized by the introduction of a computer whose suite of programmes can in a matter of minutes produce an output of information which a large drawing office would take weeks to prepare. The computer-controlled machine tool is another innovation which is altering the function of the man on the shop floor and demanding from him a fresh approach to his job.

What I am trying to say is that the engineer's traditional domains are being invaded by new forces, many of them of his own making, and the individuals and their organizations must set themselves out to accommodate these fresh elements. Will the engineer of 2070 be as different from the engineer of today as is his counterpart of a century ago? I do not think there is much doubt that the process of change will accelerate and that a hundred years of development will almost certainly, for better or for worse, produce an engineer who is a greatly different animal from the engineer of today.

If there is any significance in this fact for us of the Institute it is that we should be making sure now that as a profession we are not left behind. We must consider now in the light of future demands the problems of education, training and utilization of the individual and of how he can be helped to adapt himself to his changing environment. The Institute is conscious of the fact that these pressures on individual members must be reflected in the character of their corporate body in a variety of ways if it is to continue to perform a useful service.

Several subjects for immediate consideration present themselves. Recruitment to the engineering profession; registration at various levels; the responsibilities of the Council of Engineering Institutions (C.E.I.), together with any other federal organizations operating in the same field; the duties of the institutions and the responsibilities of the members in positions of authority in the institutions.

Since the Institute first participated in the C.E.I. it has always tried to find logical answers to problems facing the profession as a whole, even if this meant facing up to changes of the most fundamental kind. In 1967 the Institute put its view to the C.E.I. that the paramount purpose for the latter's formation was to establish an engineering qualifying and registration body comparable with other recognized professional bodies in this country. Moreover, the existence of the C.E.I. would help to further a real understanding by Government, industry and general public of the importance of the profession's part in ensuring the survival of this country as a major industrial power.

The Institute also said at that time that the health of any branch of the engineering profession was affected by the kind of relationship existing between the professional engineer and the technician engineer. The relationship between technologist and technician must be close and they should, as far as possible, be identifiable within the various professional branches.

It is the Institute's hope that the profession, particularly its own sector, should be seen to be well-ordered. The C.E.I. is a body of professional engineers constituted of special sections. Whatever its structure, it must be easily understood by members and general public alike, and this means that title and designatory letters should meet with ready comprehension. As members will recall, the Institute last year put forward proposals that the title "Fellow" should be reserved for Chartered Engineers and those of "Member" and "Associate Member" for Technician Engineers. Both categories, it was submitted, would have generic titles which meant something and designatory letters which would have significance. A man would indicate his speciality by using his own institution's letters. At the time of writing this address no decision has been taken on these proposals.

The Institute still believes that the "Member" category should be reserved for the technician and that everything should be done to encourage technicians in the profession. This should be achieved in three ways: by associating technicians as closely as possible with Chartered Engineers, by providing a means by which they may climb from one category to another, and by giving them a voice in the management of their professional body. It follows, therefore, that the Institute continues to hope that C.E.I. will be given responsibility for registering technicians in the same way that it now registers Chartered Engineers.

The idea of a common nomenclature, which could be extended to include institutions and societies at present outside C.E.I., but which might be associated in future, was one that the Institute hoped nobody would argue against. In practice, it would mean that "Fellow" of any institution would signify that the person was fully professionally qualified. "Member" would mean the same thing in the case of a senior technician, whether or not he was a member of a body associated with C.E.I.

That there is merit in extending membership of C.E.I. the Institute has no doubt. In doing this, there is much to commend the principle of grouping of institutions with similar interests. Those bodies not constituent members of C.E.I. would become associated without losing their independence and in consequence a wide range of informed opinion would be on tap. Recommendations would be channelled to the Board through the groups. Others take the view that there should be some form of affiliated membership through which all organizations would have direct access to the Board of C.E.I. Administratively this idea would have its difficulties and, in the Institute's view, would not generate the family spirit between institutions which the grouping of like interests would.

Closely associated with the question of C.E.I. membership is that of a composite register on which would be recorded the names of Chartered Engineers, Technician Engineers and Engineering Technicians. Standards of qualification would be laid down by the respective institutions who would also have to agree such things as necessary academic standards, degrees of practical experience and responsibility for registration. Operating under the Royal Charter of C.E.I., it is now understood that approval will be sought for the use of the prefix "Chartered" in the senior technician category as well as in the professional category. Obviously, there would have to be agreement by aspiring new member institutions to conform to C.E.I. rules. Among these would be a requirement to accept a common membership structure.

One must remain alive to the possibility that compulsory state registration might eventually be introduced and, in that event, it could not be assumed that the state register, based perhaps upon "safety and the public interest", would be the same as the C.E.I. register. For the young, probably for financial reasons, the C.E.I. registration might lose its attractions, and that would be unfortunate. Registration as a Chartered Engineer must be seen to be a continuing and necessary means of obtaining a recognition of professional standing and membership of an institution must be accepted as the only way to ensure that a man's technical knowledge is constantly up-dated.

In turn, the performance of the institutions must live up to this promise. Comprehensive dissemination of knowledge at all levels must be their central function by means of conferences, meetings, and selective publication. Discrimination must be exercised, of course, in the choice of subjects and costs geared to the degree of general interest in each. It is of prime importance that the cost of institution membership should never be allowed to exceed a figure which can be afforded not only by members of the profession but by aspiring entrants as well. Cost consciousness and efficiency in each institution will be reflected in the effectiveness of the entire organization. The concept as such is, the Institute believes, a stimulating challenge to all institutions to join together and present a corporate image to the advantage of the profession as a whole.

Recruitment must also rank high in the institutions' responsibilities. For example, when a young man reaches the point of deciding whether to take a pure or applied engineering course, usually at A-level plus, he should be made aware of the real value of membership of an appropriate institution. He must be made to feel welcome and be encouraged to participate in the work of the organization and in this respect the goodwill and active help of his teacher or employer is essential. Only by setting themselves out to help the young engineer can institutions hope to maintain a respected and valued position among their members in the future. In 1969 the United Kingdom Association of Professional Engineers was formed on a Trades Union basis to attract primarily the interest of Chartered Engineers employed in the private sector of industry. The Institute of Marine Engineers is in no way opposed to such an organization, but it should be made clear to individuals, particularly students, that it is not a substitute for the C.E.I. and does not provide the services which the Council or the institutions offer.

These detailed points concerning the relationship of the institutions, one with the other, and that of the individual with his own institution, are, I believe, of fundamental importance to the profession today. In the rapidly changing situation which I have mentioned earlier it is essential that the engineer should not be caught off-balance. Organization of the professional engineer on as wide a basis as possible would seem to be a logical and feasible way of ensuring that that does not happen.

And while the immediate advantages of such a step are obvious, the long term benefits could be much greater. The contribution of the engineer to our economy has never been more valuable than it is today. As the process of industrialization continues, this contribution must inevitably increase. It is for the institutions, through their members, to ensure not only that engineers are of a calibre to make the required contribution, but that their value to the community is reflected in the degree of acknowledgement which society makes of their efforts.

Marine Engineering and Shipbuilding Abstracts

No. 6, June 1970

* Patent Specification

New Engine by A/S Bergens Mekaniske Verksteder

The KV engine design is based mainly on the construction details and practical experience gained from R and L engines. It is a single-acting, four-stroke unit with from 12 to 16 cylinders and is intended for high-pressure turbocharging. The angle between the cylinder banks is 50 degrees, while the distance between cylinder centres in each bank is 480 mm.

With a cylinder bore of 250 mm and a piston stroke of 300 mm, each engine has a cylinder output for alternator drive of 134 bhp, or 139 bhp at 720 and 750 rev/min respectively, the b.m.e.p. being 11·3 kg/cm^2.

When used for propulsion purposes the engine is rated at 142 bhp per cylinder at 750 rev/min, the b.m.e.p. being 11·6 kp/cm^2 for both the 12- and 16-cylinder versions.

There are two inlet and two exhaust valves in each cylinder head, also an interchangeable starting air valve and the injection valve which is centrally located.

Each cylinder bank is fitted with a turbocharger and air inter-cooler, and due to the overall height of the latest ship alternators, these units are mounted at the forward end of the engine. The main power take-off is at the flywheel end, but for driving auxiliary machinery an extra power take-off can be provided at the forward end.

Special hydraulic tools are used for pre-stressing the staybolts, cylinder head bolts and main bearing bolts. There is also a specially designed tool for lifting and guiding the main bearing cap for inspection of the main bearings.—*The Motor Ship, December 1969, Vol. 50, p. 423.*

Gas Turbine Propulsion, Gearing and Transmission

The marine gas turbine engine is uni-directional and therefore to develop astern thrust, either a reversing gear-box or a controllable pitch propeller needs to be used. The Royal Navy has had high-power reversing gear-boxes in service since 1961. There are 37 in service with the Royal Navy in major warships, the largest of which is in the guided-missile destroyers.

Reversing is achieved by means of gear trains incorporating an idler and fluid couplings manufactured by Fluidrive Engineering Ltd. SSS (synchronous-self-shifting) clutches are used for connexion and disconnexion of the gas turbines. Troubles with these transmissions have been of a very minor nature resulting from maloperation under difficult conditions. In subsequent designs, the possibility of maloperation has been eliminated by the introduction of automatic safeguards.

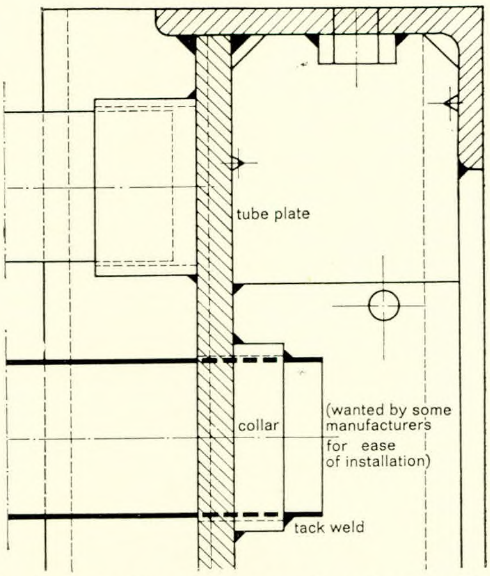
The placing of the turbines in the ship is determined by the uptakes and downtakes which in turn depend upon the hull design. The shaft positions are sited to suit the lines of the ship. This often results in a difficult gearing problem since not only does the gearing transmit the power but it also has to connect together input and output shafts which are not ideally sited. It is only by being able to use the results of NAVGRA research that sufficient flexibility can be maintained to solve these problems. It is clear then that in gas turbine installations the gearing is the elastic element in the main machinery.

To enable the Royal Navy to be in a position to design a new generation of all gas turbine propelled ships, a frigate, *HMS Exmouth,* was converted from steam to gas turbine propulsion with a controllable-pitch propeller.—*Beale, G. B., Marine Engineer and Naval Architect, November 1969, Vol. 92, pp. 467–468.*

Prevention of Air Heater Corrosion

During the past 15 years much attention has been paid to the problems of corrosion in economizers and gas/air heaters, and much investigation directed to finding a solution. KAT N.V. in Holland, believe that a valid solution lies in materials engineering.

Acids, sulphuric in nature, are formed when the temperature of the uptake gas stream falls below the dew point—say around 150°C (302°F). The settling and ionization of these acids on metallic surfaces is the cause of corrosion, and it has been found that in conventional designs of air heater—usually at the cold end—serious dissolution of metal can



Method of fitting glass-coated air heater tubes

take place after six or seven months of continuous operation. Although, obviously, considerably longer operational life does frequently occur, it is difficult to establish comparative data because of the variations in boiler operation, climatic conditions and load; all these have an important influence on the rate of corrosion.

A distinction can be drawn between "operational" corrosion and "shut-down" corrosion.

In the search for effective preventive measures a number of materials have been tested for use in gas/air heaters and economizers. These are:

Steel
Steel with copper content
Austenitic chrome-nickel steels
Steel with lead coating
Glass
Glass-lined or coated steel

Steel tubing which has been coated, or lined, with glass offers the most effective combination—the glass will stand up to the corrosive environment while the steel supplies the stress resistance to keep the glass intact.

Glass-lining of steel is accomplished by melting down one or more coats of finely pulverized glass on to the steel. After the melt has been cured at 1600°F a glass film, having a thickness of approximately 0·02 in is securely bonded to the steel. For this purpose a "short" glass is used, having a melting point of 1520°F. This glass/steel combination has a high resistance to impact and stress, retaining the flexible qualities of the steel tube.

Fitting the glass-coated tubes is quite simple. They are not rolled into the tube plate, instead a new procedure was tried and later on perfected. The tube plates are bored to the final dimensions of the tube. The tube is then moved into place and tack-welded to one tubeplate only, with three tacks. The welds are made on the hot end, allowing the tube to expand freely at the cold end. This tack-welding is carried out electrically and since the glass is melted by the heat of the arc the weld is made on to the base metal of the tube. This weld has been proved satisfactory in long years of operation. A slight gap remaining between the tube plate and the tube can be sealed by means of a special paste which is supplied by John Manville. In a number of cases no paste was used and the resulting air losses could not be measured. Sometimes an extra sleeve is used to tack-weld through so that the welded area is kept hot at all times. The glass film is quite thin, about 1/100 to 2/100 of an inch, and therefore has virtually no effect on the overall heat transfer.—*Marine Engineer and Naval Architect, February 1970, Vol. 93, P. 111.*

World's Largest Liftship

The world's largest ocean-going lift ship was recently launched at the shipyard of the Rotterdam Dockyard Company, Rotterdam. The craft is under construction for W. A. van den Tak's Bergingsbedrijf N.V. Rotterdam.

Taklift I measures 2370 grt and her dimensions are as follows: length over 60 m; breadth of hull 23·4 m; depth 5·6 m. The propulsion machinery to be installed in the engine room will consist of two MWM Diesel engines each of 530 hp at 1800 rev/min. These engines will drive two c.p. propellers and will give the craft a speed of 7 knots. *Taklift I* will also be provided with a 220 hp bow thruster, enabling her to operate without the assistance of a tug.

The two main engines will also drive the generators supplying 526 kW d.c. and 224 kW 3-phase a.c.

The lifting gear of the vessel includes an 800 ton sheerlegs and a special wreck grab suitable for lifting pieces of 400 tons. The grab has an own weight of 100 tons and continues to be operational at a depth of up to 150 ft. The electrically driven winches of the lifting gear are centrally controlled from the wheelhouse, which is also provided with the latest aids to navigation and communication.

Taklift I has been designed for lifting sunken vessels as well as the removal of heavy objects, such as reactors and generators, etc., up to a maximum weight of 800 tons and 1000 tons respectively.—*Holland Shipbuilding, November 1969, Vol. 18, p. 75.*

Marine Safety

Marine safety concerns, in particular, safety of life at sea. If a completely safe ship cannot be produced, optimum safety must be the target.

The interpretation of 'optimum safety' can be very wide so it is desirable that for ships on international voyages, broad international standards of safety are agreed. These are decided at international conferences resulting in agreed international conventions applicable to all countries accepting the convention.

The author suggests the causes of shipping losses to the world fleet may be a guide to the nature of the casualties affecting safety of life at sea.

Fire appears to be the major safety hazard on a ship and fire protection, prevention, detection and extinguishing arrangements can be adopted to reduce the hazard.

Unattended machinery spaces present particular safety problems but when more experience with such arrangements is obtained it will be possible to consider the necessity for any additional safety measures.

The general principles governing life-saving appliances have altered very little over the years, except for the use of inflatable life-rafts.

World shipping losses are increasing and in the interests of safety some consideration must be given to the adoption of means to reduce them.—*Whiteside, H. N. E., Paper presented at the IMAS 1969 Plenary Session; Transactions of The Institute of Marine Engineers, December 1969, Vol. 18, pp. 405–409.*

The Stradler as a Fishing Vessel

With food from the sea becoming increasingly important in order to feed the rapidly expanding world population, improved methods of catching and transporting fish to the market place are urgently needed.

The Stradler Ship can proceed to the fishing grounds rapidly in almost any kind of weather because of her size and speed. The helicopter, carried on board, can locate schools of fish by visual and electronic means covering a wide area around the ship, thus saving a great deal of time.

As the ship approaches the fish, the scoop is lowered. The leading edge of the scoop could extend approximately 100 ft below the surface of the ocean. Then, proceeding forward at a slow speed, the ship scoops up the fish. The principle is the same as trawling but is more efficient and faster. The scoop of the barge and the ship can range to any width as desired.

The fish flow into the barge carried between the hulls of the catamaran Stradler. The interior of the barge is divided into many transverse bins which are separated by screened partitions. The mesh in these partitions becomes increasingly smaller from the forward end to the aft end. This automatically grades the fish—the largest fish are trapped in the forward bin or basket and the smallest fish in the aft basket. In between are intermediate sizes of fish.

When fully loaded, the scoop is retracted and the ship returns to port. Once in port, the Stradler releases the fish barge which is pulled out of the stern opening in the catamaran hull. Shore cranes can lift each bin onto shore for immediate selecting and processing of the fish.—*Arcos, M. D., Maritime Reporter/Engineering News, 15 November 1969, Vol. 31, p. 33.*

Coastal Tanker for Thailand

A small twin-screw products carrier has been built by Robb Caledon Shipbuilders Ltd., for the Thai Petroleum Transports Co. Ltd. This vessel, *Suvarnabhumi*, 3750 dwt, will be employed mainly in Thailand coastal waters; but is also suitable for operation in open sea passages under all weather conditions.

Principal particulars are:

Length, o.a.	106·00 m
Length, b.p.	97·54 m
Breadth, moulded	15·08 m
Draught, loaded	4·65 m
Deadweight	3890 tons(M)
Gross tonnage	3188·75
Displacement	5470 tons(M)
Lightweight	1580 tons(M)
Machinery output	2400 bhp at 750 rev/min
Service speed	11 knots

Suvarnabhumi has been built to Lloyd's Register Classification ✠ 100 A1 Oil Tanker/CC ✠ LMC and has her machinery and accommodation aft. The semi double-skin structural arrangement of the cargo tanks provides independent wing ballast tanks, and serves to eliminate the risk of pollution of confined waterways from ballast/product mixing or tank washing.

On the main deck forward there are two 75-ton capacity LPG tanks which are used for the carriage of butane and propane gases under pressure at ambient temperature. The LPG system is based upon direct loading through the internal spray line or vapour return, and discharging by means of two hydraulically-driven Ingersoll-Rand compressors with intakes for shore side vapour. The designed discharge rate of the equipment is 30 tons/h.

Each of the three cargo pumps is direct-coupled to a Deutz air-cooled Diesel engine type A12 L714 developing 165 bhp at 1500 rev/min. The driving shafts pass through the forward engine-room bulkhead through a Stothert and Pitt gastight gland. A Twiflex centrifugal clutch arranged to cut-in at 650 rev/min is fitted between each engine and pump.

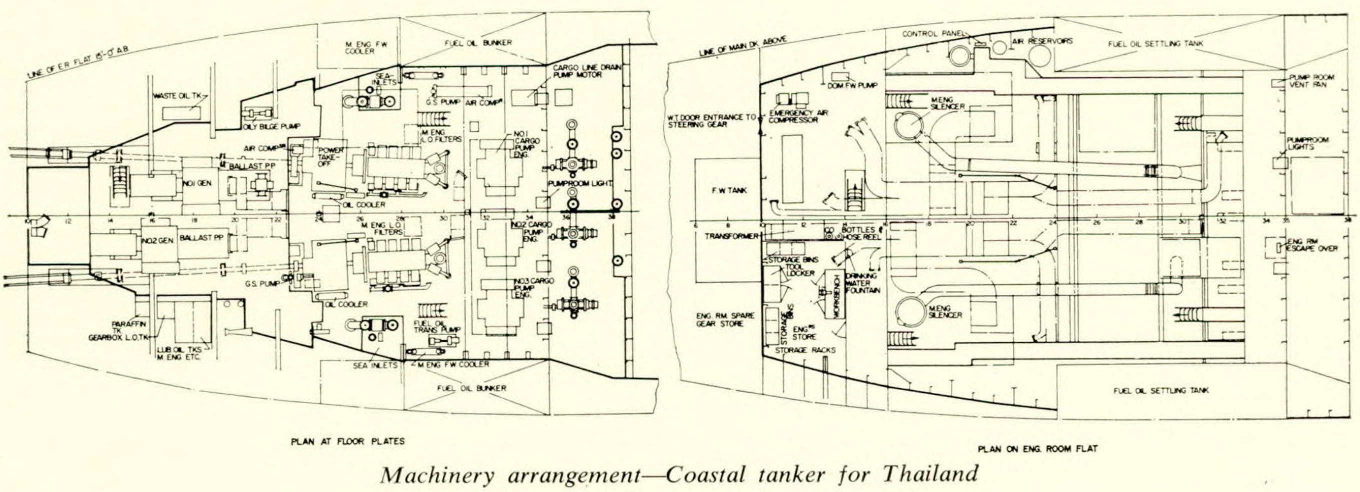
Suvarnabhumi is powered by twin English Electric type 8CS VM Diesel engines each of 1200 bhp designed continuous rating, derated for tropical service to 900 bhp. The engines are fitted with Brown Boveri turbo-chargers and have a service speed of 750 rev/min. Each engine drives its propeller shaft through a Modern wheel Drive M2WR reverse/reduction gear-box, having a 2·85:1 ratio ahead and astern, giving a propeller speed of 263 rev/min.—*Shipping World and Shipbuilder, February 1970, Vol. 163, pp. 280–283.*

Series of Large Tankers from Götaverken

With the delivery of their first 227 000 ton tanker, AB Götaverken, whose largest tanker to-date has been 120 000 dwt, has entered a new stage in the firm's history. This vessel, named *Veni,* which has been built for Smedvigs Tankrederi A/S Stavanger, is the first in a series of eleven tankers of 227 000 dwt which Götaverken will build for Swedish and foreign shipowners. The ship's principal dimensions have been determined by utilizing the dock to its optimum capacity, so that the best possible deadweight, cargo capacity and speed characteristics could be obtained. *Veni* is not only the largest ship yet delivered from a Swedish shipyard but also the largest in the Norwegian merchant fleet. All eleven vessels will be powered by Stal-Laval steam turbines designed for an output of 32 540 shp, giving a speed of 16 knots fully loaded. A second ship, *Alva Star,* is nearing completion.

Principal particulars:

Length, o.a. ...	1090 ft 0 in	332·23 m
Length, b.p. ...	1050 ft 0 in	320·04 m
Breadth, moulded	149 ft 7 in	45·59 m
Depth, moulded ...	... 87 ft 6 in	26·67 m
Draught, summer	... 67 ft $10\frac{1}{8}$ in	20·68 m
Deadweight ...	... ...	227 425 tons
Gross tonnage ...	... ...	113 532
Cargo capacity ...	... ...	9 933 000 ft^3
Ballast capacity ...	... ...	962 000 ft^3
Machinery output	32 540 shp at 86 rev/min	
Service speed ...	... ...	16 knots



Machinery arrangement—Coastal tanker for Thailand

The new ship has been built with her machinery, navigating bridge and all accommodation aft.

The cargo pump room is located forward immediately of the machinery space and contains four steam-driven Eureka vertical cargo pumps, each of 400 tons/h capacity. There is also a steam-driven ballast pump having a capacity of 3000 tons/h. For the cargo pumps there is a common stripping and capacity control sytem. A compartment on the port side of the first poopdeck contains equipment for the remote operation of the pumps and valves in the cargo oil and ballast system.

The main turbines, with the gear-box and condenser, are located at floor level. Above, on the first platform are the two main boilers. On this platform there are also the control room and all the important auxiliary machines, such as the main and standby generator, main feed pumps and evaporators.

The main turbine consists of a high-pressure turbine and a low-pressure turbine arranged in separate casings. The astern turbine is fitted in the discharge end of the low-pressure turbine. The turbines rotors are of forged construction and only the astern turbine's two Curtis wheels are shrunk on. Exhaust takes place axially into the main condenser which is located immediately forward, and in the same plane as the main turbine. The main condenser has pump circulation.

The turbine has triple reduction on the H.P. side and double reduction on the L.P. side. The primary reduction (for the H.P. turbine the two first reduction stages) is by means of planet gearing, while the last reduction stage is carried out in the normal way. A separate propeller thrust block has been fitted aft of the gearing.

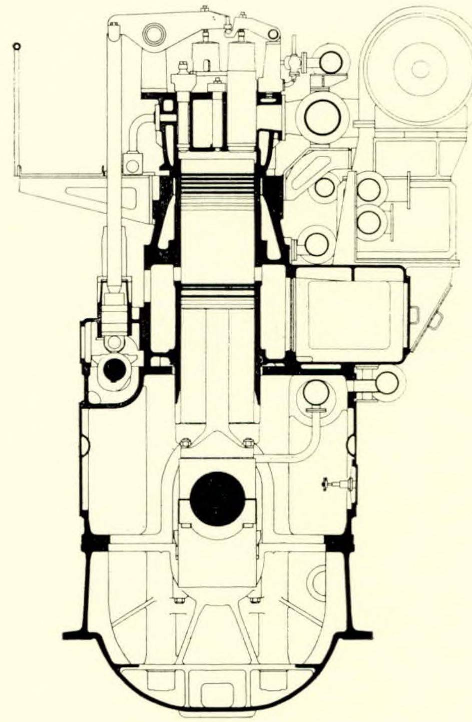
Both the high-pressure and astern turbines are driven by superheated steam at 63·3 kg/cm² and 510°C. Steam flow is controlled by a separate electro-hydraulically operated manifold combining two combined regulating and rapid-closing valves for the H.P. and astern turbine respectively.

Steam is generated in two oil-fired watertube boilers of Babcock and Wilcox type made by AB Götaverken. Each boiler has a maximum capacity of 71 tons of steam/h. Pressure at the superheater outlet is 64·7 kg/cm² and the steam temperature 513°C. Steam is passed through a desuperheater located in each steam drum and reduced to 365° (maximum). —*Shipping World and Shipbuilder, December 1969, Vol. 162, pp. 1694–1699.*

Mitsubishi Medium Speed Engines

Two ranges of medium-speed engine designed at the Nagasaki works are built by Kobe Hatsudoki and Akasaka Iron Works, both licensees of Mitsubishi Heavy Industries. These differ from the European concept of a medium-speed engine in that they are much slower in running to suit the local demand for coasters, trawlers, etc. The smaller of the two, the UET 45/75C has a cylinder bore of 450 mm (17·7 in) and piston stroke of 750 mm (29·5 in) and a cylinder output ranging from 633 at 230 rev/min in the case of the six- and nine-cylinder engines to 625 bhp in the case of the eight-cylinder engines. These correspond to b.m.e.p. of 10·39 and 10·25 kg/cm² 148 and 146 lb/in²) and a mean piston speed of 5·75 m/s (1130 ft/min). This is a cast iron "three-piece" engine with main bearings in the bedplate, separate crankcase and cylinder jacket. The engine is of conventional uniflow scavenging two-stroke design, with three exhaust valves operated by push rod and rocker arm per cylinder. Trombone pipes convey cooling oil to the piston crowns. A Mitsubishi MET turbocharger delivers air through an intercooler to the scavenge trunk which is provided at the exhaust side of the engine.

The larger UET 52/90C engine of 520 mm bore (20·5 in) by 900 mm piston stroke (35·5 in) is made with six, seven, eight and nine cylinders and covers a power range from 5200 to 7800 bhp at 195 rev/min. Here the b.m.e.p. range is 9·96 kg/cm² (141·5 lb/in²) for the eight-cylinder to 10·46 kg/cm² (148·5 lb/in²) for the six- and nine-cylinders with a mean piston speed of 5·85 m/s (1150 ft/min).



UET 45/75C engine

The engine is similar to the UET 45/75C being trunk-piston single-acting two-stroke uniflow scavenging and direct-reversing design with three exhaust valves in the cylinder head and a two-part oil-cooled piston. This engine incorporates a timed cylinder lubrication system developed by the Mitsubishi which makes it possible to economize in the use of expensive cylinder oil.—*Marine Engineer and Naval Architect, January 1970, Vol. 93, pp. 20–21.*

Slamming Control Equipment

Bottom damage over a particular area at a percentage of the ship's length aft of the forward perpendicular is not a new problem and the need to limit the amount of damage is recognized by the various classification societies, They have formulated rules which define the area likely to be affected and also the scantlings, etc, of the structure designed to strengthen the bottom forward. Ships in service operate in general between the basic conditions of ballast and full load and enter the danger zones when meeting heavy seas while other factors influencing the onset of slamming are: length, ship's lines, speed, draught and longitudinal radius of gyration. The most important motion is pitching where the amplitude of the vertical movement is large. However, despite the steps taken at the design stage to reduce the possible damage due to panting and so to save repair bills and financial loss due to the ship 'out of service' it is the Captain who, by his handling of the ship, is the most important factor in minimising the extent of bottom damage. To reduce the dependance upon individual judgment and to provide officers with the relevant data regarding ship motion and strains there has been developed, by the National Physical Laboratory, for Manchester Liners Ltd. "Slamming Control Indication Equipment" which is now being manufactured by Brown Brothers and Co. Ltd. and of which a set is at sea on board *Manchester Challenge*. The information supplied by the gear enables the master and his officers to assess the situation and make decisions regarding course and speed which can be maintained in the prevailing conditions of weather, sea state, ship's loading and trim. The equipment indicates bow emergence frequency and acceleration and hull plating deflexion. Basically for impact of measurable amplitude to occur when the forefoot emerges and re-enters the sea the relative velocity between the ship's bottom and the water at re-entry must exceed a specific threshold velocity which varies with draught and emergence and pitching period. The equipment includes two emergence indicators which are fitted forward while pressure under the keel is applied to a diaphragm on a pneumaticatic control panel. When the pressure falls to within a few inches of water gauge of atmospheric pressure the diaphragm moves and operates an electric switch linked with the bridge instrument panel where a lamp flashes to indicate emergence of the bottom which is registered on a counter unit.

Regarding the effect on the bottom plating of slam pressures, these can cause deflexions beyond the elastic limit until eventually fatigue sets up cracking. The deflexions are monitored continuously and the amount displayed on the bridge panel where permanent set, should it occur, is shown by a lamp. High pressure created when slamming occurs causes deceleration of the bow of up to $1g$ and even up to $3g$ under severe conditions. Although this is of short duration a two-node vertical vibration of considerable duration is set up which, due to its higher frequency, results in larger acceleration particularly forward, and an accelerometer enables the vertical acceleration at this point to be continuously indicated on a bridge instrument calibrated from $-2g$ to $+2g$ and marked with a danger zone.—*Shipbuilding International, December 1969, Vol. 12, p. 34.*

Instantaneous Pressure Measurement in Injection Systems

Extensive testing with numerous engines of different manufacture has indicated that many types of operational defects such as worn pump plungers, cams, crankshaft bearings or broken plunger springs, incorrect pump volume settings, worn or incorrect delivery valves, stuck or intermittently sticking nozzle needles, leaking or coked nozles and high or low opening pressures can be detected by this electronic equipment operating through the detection and measurement of instantaneous pressures in the injection system lines of Diesel engines. With this method, pressure signals from the Diesel engines first cylinder are used to produce synchronization with crankshaft rotation. Signals are devised from, calibrated quartz pressure transducers readily inserted in the lines. No other connexions to the engine are required and hook-up can be made quickly. Traces for each injection line are then displayed on a conventional cathode ray engine analyser, shown in a vertical arrangement to permit immediate comparisons. The instrument also includes circuitry that gives precise measurement of nozzle static opening pressures as well as timing and timing advance at various speeds. It is particularly effective with Diesel engines employing the Bosch-type unit injector systems, and the improved maintenance made possible by the equipment produces much reduced smoke emission.—*Reed's Marine Equipment News, October, 1969, Vol. 13, p. 18.*

Long-term Economics of Piston Groove Protection

The need for some kind of piston ring groove protection in the form, for instance, of loose or fixed insert rings, has long been recognized by engine builders and users. The technical advantages of more advanced methods of piston ring groove protection have already been recognized by those engine builders who now make groove protection standard or offer this as an optional arrangement in current production. Users have also adopted these methods in yet other types of engine which were not so equipped when new. The choice of such advanced protection in these latter cases is often inhibited by the necessity of submitting a yearly account of expenditure. In this, the extra cost of groove protection will understandably, be considered for that year in isolation by the financial department, in the absence of any longer term economic assessment.

It is the purpose of this article to examine the overall costs, direct and indirect, of various types of groove protection during the life of a typical large-bore low-speed Diesel engine as well as to summarize the requirements for such grooves and the results obtained with them in service.

Broadly, three requirements should be met to obtain optimum piston ring and cylinder liner performance:

Freedom from deposits on the groove surfaces: hence freedom of the ring to move.

Maintenance of a good guide and support for the piston rings.

Minimum thermal barrier between the ring and the piston body (for some engines).

Experience in service suggests that all three of these requirements are met by a suitable chromium coating on one, or preferably both, groove sealing surfaces. This is discussed below.

Single chrome grooving (S.C.G.) is defined as a layer of hard chrome on the lower surface of the groove. Double chrome-grooving (D.C.G.) is defined as a similar layer of chrome, but applied to both the upper and lower groove surfaces. Such chromium has a surface hardness of about 950 VPM. Orthodox grooves are defined as those having only the lower surface protected, by a caulked or welded insert ring, this being the most common traditional method.

It is a matter of common experience that carbonaceous deposits form and adhere tenaciously to groove surfaces made of cast iron or forged or cast steel. These products do not adhere to chromium, however, and chromed grooves can be cleaned by wiping. This results in freedom from ring sticking, and its consequences, and practically eliminates the most tedious and time-consuming operation entailed in the overhauling of a piston and renewal of piston rings.

The coefficient of friction of chromium against cast iron under conditions of poor lubrication is about half that of cast iron against steel. The carbonaceous deposits existing with the latter combination will increase the friction by another order of magnitude above that of chrome against cast iron.—*Ruscoe, A. D., The Motor Ship, November 1969, Vol. 50, pp. 358–361.*

Standard Machinery in a Dredger Fleet

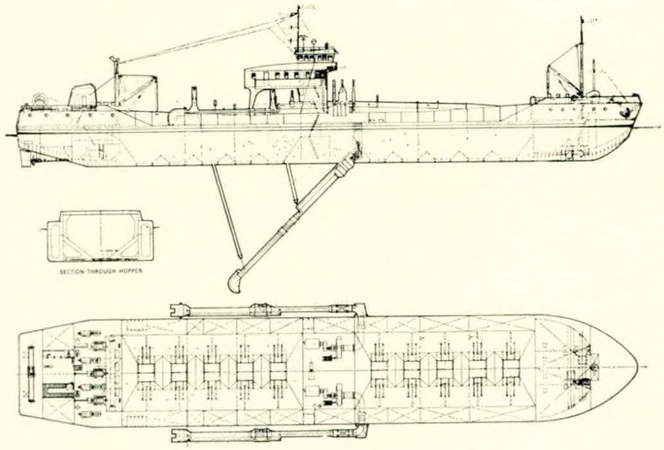
Taybol Ltd. have ordered six 3000m³ (106 000 ft³) suction hopper dredgers from yards in Great Britain and Germany, and six hopper barges from German yards.

The first two ships, *Transmundum I* and *Transmundum II*, were delivered by Cammell Laird (Shipbuilders and Engineers) Ltd. last year and the remaining four of this class are under construction in the yard of Norderwerft (Köser and Meyer) of Hamburg. These ships have the following principal particulars:

Length, o.a.	95 m (311 ft 8 in)
Breadth	16 m (53 ft 6 in)
Depth	6 m (19 ft 8 in)
Load draught	5 m (16 ft 5 in)
Hopper capacity	3000 m³ (3910 yd³)
Deadweight	5000 tons
Speed	10 knots

The pump room is amidships and contains two 800 hp dredging pumps drawing through 800 mm (32 in) suction tubes fitted with pressure jets at the head. The maximum dredging depth is 25 m (82 ft). The pumps deliver to launders leading fore and aft over the hoppers, each of which have five horizontal double-slide bottom doors. The dredging bridge, amidships, surmounts an accommodation deck and twin motor-driven bow thrusters forward assist in manoeuvring in a congested or narrow waterway.

It is in the machinery installation that these ships are unusual. They have triple Seffle-cp propellers, each driven by



Arrangement of dredger

a Dorman 12QTCWM 12-Vee turbo-charged and charge-cooled engine of 827 bhp at 1800 rev/min mcr through a 4·5 to 1 Lohmann reduction gear-box. This configuration, as can be seen from the drawing, makes possible an exceptionally short propulsion engine-room with corresponding gain in hopper length. The dredging pumps are driven by two engines of identical type and rating through reduction gear-boxes and flexible couplings.

Auxiliary electrical services are provided by four 315 kVA 1500 rev/min Diesel alternator sets, each consisting of a Dorman 6QTCWM six-cylinder in-line turbo-charged and charge-cooled engine having cylinder dimensions identical to those of the main propulsion and dredging engines: 6·52 in (158·75 mm) bore by 6·5 in 165·1 mm) stroke. Each dredger has two 75 kVA emergency stand-by and harbour service generators driven by a Dorman 8DA/M Vee-8 air-cooled engine of 94 bhp at 1500 rev/min.

The six hopper barges have two Dorman 8QTCWM Vee-8 turbo-charged and charge-cooled engines rated 1000 bhp at 1625 rev/min driving the propellers through 4 to 1 reduction gear-boxes. These engines also drive, from the forward end, a 200 m^3 jet pump for clearing the hopper doors, an hydraulic pump for the door rams and a 2000 kW dc generator. In these craft there is a 55 kV alternator powered by two Dorman 3DA/M three-cylinder in-line engines, one driving each end of the alternator shaft.—*Marine Engineer and Naval Architect, February 1970, Vol. 43, pp. 61; 63.*

The Patboon Lift, a New Ship Lift

In the last few years various types of ship's lifts have been added to the existing facilities for the drydocking of ships. Most of these lifts are hydraulically operated but some are mechanically operated. Van der Giessen-De Noord, Krimpen a.d. IJssel, considering an expansion of their repair capacity have investigated practically all the existing possibilities, but found that all of them had one or more drawbacks.

As a result, the design department of Van der Giessen-De Noord developed an arrangement which eliminated practically all of these drawbacks. The design has been thoroughly tested by the repair staff with the aid of a model; its hydraulic properties were critically judged and its remunerativeness investigated. The results were so promising that the design could be regarded as an invention and it was decided to apply for a patent. Progress has been such that it is now possible to publish the following description of the longitudinal version of the Patboon lift.

A concrete bedplate, which may or may not be supported by piles, is placed in the bed of a river or harbour. Its length is about equal to the chosen ship's length and its width is about 5 m. Pivot joints are provided in this plate at distances of, for example, 3 m across. This part could be referred to as the foundation.

Next, a second platform is made of steel, either with or without a bouyancy of its own, and corresponding in width and length with the foundation. The width of this platform is extended with a considerably higher construction to obtain the working space required around the ship. Like the foundation, the underside of the steel platform is provided with pivot joints.

This second part is called supporting or working platform. The framework yokes fitting into the pivot joints. The length of these yokes depends on the water depth in the river or harbour, the draught of the ship and the height of the land.

If a, mainly horizontal, force is exerted on the supporting platform, each point of this platform will move through the arc of a circle whose radius will be equal to the length of the yokes. If at the start of the operation the platform is at its highest point, it is provided with the required blocks and shores for accommodating the ship to be docked and is then lowered to the point where sufficient draught is obtained. The ship can be kept in the desired position by lines connected to two bitts ashire and to a tug. A pull, which may be mechanical or hydraulical, may now be exerted on the platform. As a result of this pull the platform will rise, reach the keel of the ship, then eliminate any trim that may be present and finally lift it up to the desired or extreme height.

For this manoeuvre it is important that the ship's own displacement and any buoyancy the platform may have, co-operate when the power required is at its maximum. When the highest point has been reached, the horizontal force has decreased to zero and a simple bolt will keep the platform with the ship in equilibrium.—*Holland Shipbuilding, October 1969, Vol. 18, p. 125.*

Thermal-Powered Multi-Fuel Engine

High hp/lb and high hp per pound Sterling are two of the leading claims made for a thermal powered engine of a new design at present undergoing tests. Designed by Mr. Patrick F. Howden, of London, the engine operates by using principles of fluid expansion which are said to have been known for some time but so far unused in an engine of any type. It is claimed to be capable of operating on almost any known fuel or heated fluid.

Capable of being constructed from light alloys, except for bearings and shells, the design is claimed to require only the minimum of precision and limited skill in its assembly and maintenance. Furthermore, a wide range of outputs from less than 1 bhp to the maximum envisaged at present can be produced from the basic design.

The thermal engine is said to be silent in operation and capable of cold starts, while engine performance is claimed to be more predictable than present conventional engines.—*The Motor Ship, December 1969, Vol. 50, p. 396.*

Gyroscope Used in Controlling Loads Hung from a Cable

A machine, called Gyrotator, has been developed that is capable of the complete control of a load, such as a filled container, suspended from a single cable. The unit does not exert a twisting force on the cable from which it is suspended. To be used with a spreader frame of which it is an integral part, it is essentially a large gyroscope.

The Gyrotator is seen as an alternative to the tagline method of controlling loads suspended from a single line. In the case of a loaded container, this method is said to be time consuming and dangerous for the stevedores handling the lines. This is thought to be the first time the energy generated by the flywheel has been utilized.

In application, the Gyrotator is mounted in the middle of the spreader frame and controlled by the operator of the crane. Upon being activated, the flywheel tilts generating torque that turns the container.

The first actual use of the machine will be on four Farrell Lines ships equipped with Thomson cranes for handling containers from the eight forward hatches. The machines for the Farrell Lines will be hydraulically driven as the spreader frames—which will include automatic, self-levelling devices—will be hydraulic.

The Gyrotator is designed initially for 20 ft and 40 ft containers but can be engineered to accommodate any size load by varying the size and speed of the flywheel to fit particular conditions.

Another feature of the machine is that the rotational position of a load can be held while the crane is slowed by using the Gyrotator as a stabilizer.—*Marine Engineering/ Log, November 1969, Vol. 76, p. 112.*

New Propeller Research Laboratory

A large propeller research and testing laboratory is to be built on the Karlstads Mekaniska Werkstad (Kamewa) industrial estate at Kristinehamn, Sweden, which will give this manufacturer research facilities for the more advanced methods of ship propulsion now being considered. These include such systems as jet propulsion of hovercraft and air lubrication of propellers, together with development work on hydrofoil propulsion.

The laboratory will house two cavitation tanks for model tests, and one of the tanks will replace the present Kamewa cavitation test tank originally commissioned in 1943. It will be of the closed type with an overall length of 14 m, height 8m, and a water velocity of 12 m/sec will permit tests to be carried out under a vacuum corresponding to practical maximum ship speeds.

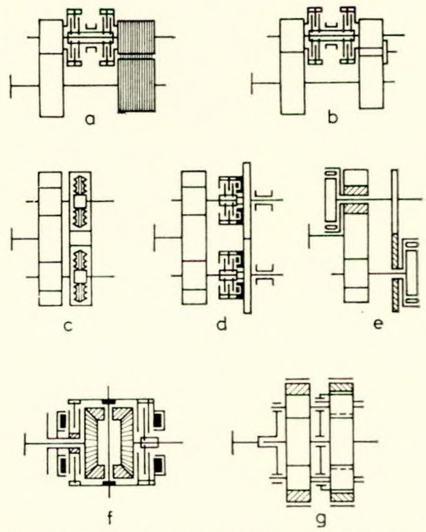
The second tank unit will have a free water surface 25 m long and 12 m high with an approximate volume of 400 m^3. A 1300 hp pump will provide a maximum water velocity of 12 m/sec and the vacuum setting will be adjustable, as required. It is thought that this tank will also open new fields for Swedish research and the Kamewa laboratory will continue to undertake test projects for other companies. The conventional closed tank at Kamewa is of moderate size and it is not intended to extend this facility, as a large tank of this type at the National Shipbuilding Experimental station at Gothenburg is available.—*The Motor Ship, November 1969, Vol. 50, p. 363.*

Power Transmission for Medium Speed Engines

The increasing use of medium speed engine geared installations for propulsion purposes has led to many developments in the design and manufacture of reverse/reduction and reduction gearing for these units.

Reversing gears generally fall into three basic groups shown in the diagram: gears with two main wheels (a) and (b), with one main wheel (c) to (e) and with planetary wheels (f) and (g). The first type has a relatively large overall length; because of this and owing to the fact that the load carrying capacity of these gears is not always identical for both directions of rotation, they are only suitable for low outputs.

Gears with one main wheel, however, are built in large units; the engine output is transmitted to a clutch shaft with the clutch engaged, to one of the two input pinions. When this clutch is disengaged, the other can be closed hydraulically so that the output is transmitted via the pair of reversing gear wheels—rotating in the reverse direction—on to the other output pinion and the common main wheel. Here, the two sets of elements are designed for the same capacity, which means that the direction of propeller rotation and that of engine rotation are of no importance. Reversing gears with planetary wheels are frequently confined to the low-capacity range—probably due to their complicated design and hence expense, and the planetary wheel bearings which are extremely sensitive at high peripheral speeds.



a) unit using two main gear wheels and a chain drive
b) two main gear wheels with a reversing pinion
c) unit using one main wheel with plain vee-groove clutches
d) with multi-plate clutches
e) with external plate-type clutches
f) planetary layout with bevel gears
g) with spur gears

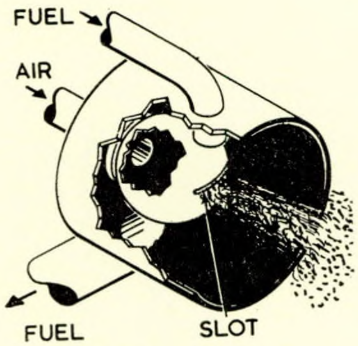
Various reversing gear arrangements

A distinction is made in reversing gears with a single main wheel between external and internal clutches. The former are generally preferred for marine reversing gears, as this type of clutch is easily accessible from outside and the operational heat is absorbed by the surrounding atmosphere, furthermore, its freedom from backlash makes it suitable for any kind of Diesel engine. On the Continent internal multi-plate clutches are often used which are operated hydraulically. The clutches with plain vee-grooves, formerly in wide use, are seldom encountered nowadays; this is probably due to the fact that they were intended solely for non-hardened, i.e., heat-treated, gears. In the case of marine reversing gears, however, small-sized units can only be obtained with hardened spur gears. Thus, the multi-plate clutch integrated with the spur gear has become firmly established in this field. The unavoidable axial movement of the plates necessitates a certain amount of backlash between the plate teeth and those of the internal and external plate carriers. Despite this, the phenomenon known as "hammering-in" of the plate teeth has rarely been observed on reversing gears.—*Hiersig, H. M., The Motor Ship, February 1970, Vol. 50, pp. 549–552.*

Clog-free Atomizer

Most fuel-oil burners break up the fuel by forcing it at high pressure through a plate containing a number of small orifices. Although efficient atomization of the fuel can be achieved in this way, the drawbacks of such a system are the requirement for a source of high pressure and the difficulty of selecting the correct orifice size, as holes small enough for good atomization are easily clogged by contaminants in the fuel. It now appears, however, that both these drawbacks have been overcome simply and effectively by a new approach to atomizing, designated Una-Spray, developed in the U.S.A. by the Rocketdyne Division of North American Rockwell.

As shown in the accompanying figure, the fuel nozzle in the new system is a hollow dome provided with a slot for an orifice. Low-pressure fuel flows over the external surface of



Clog-free atomizer

the dome from above, while low-pressure air is fed into the interior of the dome and expands through the slot. As a result, it breaks up the film of fuel into an extremely fine mist, any unatomized fuel being collected and recirculated. Because the fuel passes over the exterior of the dome, any contaminating particles in it are not directed through the slot but away from it, without disturbing atomization and without any risk of clogging.—*Machine Design, U.S.A., 8 January 1970, p. 126; Engineers' Digest, Vol. 31, March 1970, p. 5.*

First of Three Fast 7000 dwt Tankers for Fleet Auxiliary

Green Rover and her sisterships *Blue Rover* and *Red Rover*, now fitting out, have been built by the Hebburn shipyard of the Swan Hunter Group to the order of the Ministry of Defence (Navy) and are designed to replenish naval ships at sea with marine and aviation fuels, fresh water, a limited amount of dry cargo and refrigerated stores. Four fuels are carried, namely boiler fuel, Diesel oil, aviation spirit and petroleum.

This is the R.F.A.'s first venture into propulsion by medium-speed, high-powered Diesel machinery, an installation partly introduced to enable maintenance work to be undertaken with the ship under way.

Principal characteristics of the *Green Rover* are as follows:

Length, o.a.	461 ft 0 in
Length, b.p.	430 ft 0 in
Breadth, moulded	63 ft 0 in
Depth, moulded to upper No. 1 deck	33 ft 6 in
Tonnages:	
Deadweight capacity	7060 tons
Corresponding draught	24 ft 0 in
Underdeck tonnage	5846·62
Gross register	7503·07
Net register	3186·05
Cargo capacity:	
total (100 per cent)	308 468 ft^3
Oil fuel capacity	42 890 ft^3
Fresh water	1797 tons
Personnel	48
Service speed	approximately $17\frac{1}{2}$ knots

The main propulsion machinery comprises two Ruston AO vee-form, turbo-charged two-stroke unidirectional space-frame engines, fully equipped to burn residual fuel (generally of about 600 sec. Red. 1). Each of these 16-cylinder engines, normally rated at about 8000 bhp at 450 rev/min with a b.m.e.p. of 150 lb/in^2, drives through a Fawick/Metalastik isolating clutch coupling to an M.W.D. twin-input, single-output 3:1 reduction ratio gear-box. This drives the Kamewa c.p. propeller at 150 rev/min. Such an installation has been selected largely because of the very precise control of ship speed which can be attained while refuelling operations are in progress with the ship under way.

Either engine can be disconnected when propulsive power demands are low and all manoeuvring of engine speed and propeller pitch is controllable by a pneumatic system from either the bridge or the machinery control centre in the engine-room.

The M.W.D. gear-box transmits the 8000 bhp from each engine at 11 ft 6 in nominal centres, the gearwheels being of the double-helical type. Both input shafts rotate clockwise, while the output shaft rotates anti-clockwise when looking forward.

Auxiliary electrical load is provided by seven Diesel generating sets, each comprizing a Paxman 8RPHCZ eight-cylinder pressure-charged intercooled Diesel engine driving an English Electric 340-kW alternator at 1200 rev/min. The supply is 440 volts, three-phase, at 60 cycles/sec. In addition, the three cargo pumps are driven, as previously explained, through clutches by Paxman 447 bhp 1500 rev/min engines of the 8RPHCZ type. One of these engines has the dual function of either driving the cargo pump at 1500 rev/min, or acting as a standby to the main generator sets by driving an English Electric 340-kW alternator, coupled to its free end, at 1200 rev/min. The main alternators are arranged for continuous parallel running and are of the enclosed, ventilated, drip-proof type.

The Diesel alternators have remote sequential start operable from the machinery control room and a governor remote speed control at the main switchboard for synchronizing. In addition, a remote speed governor control which can be supervised from the cargo pump control position is fitted to the dual-purpose machine.—*The Motor Ship, December 1969, Vol. 50, pp. 384–389.*

World's Largest Bulk Carrier

A bulk carrier of 160 242 dwt has been built by Ishikawajima-Heavy Industries Co. Ltd., at their Kure Shipyard for National Bulk Carriers Inc., of New York, U.S.A. This vessel *Universe Aztec*, is the largest vessel of this type yet built, and is engaged in carrying industrial salt from Mexico to Japan. Powered by steam turbine machinery the ship has a service speed of 15·5 knots.

This new vessel has been built under special survey to the ABS classification ✠ A1 E 'Bulk Carrier' and ✠ A.M.S., to carry salt at 30 ft^3/ton, iron ore at 17 ft^3/ton and coal at 44 ft^3/ton. She has a single continuous freeboard deck, forecastle and six tiers of deck houses, a bulbous bow, raked stem and cruiser stern. Navigating bridge, machinery space and all the accommodation have been arranged aft.

There are six cargo holds of equal length, each having two hatches. It is possible to load salt, coal and ore in all the holds with an even keel.

Principal particulars are:

Length, o.a.	990 ft $9\frac{3}{4}$ in
Length, b.p.	951 ft $5\frac{1}{4}$ in
Breadth, moulded	142 ft $0\frac{3}{4}$ in
Depth, moulded	81 ft 0 in
Draught, extreme	57 ft $2\frac{7}{8}$ in
Deadweight	160 242 tons
Displacement	187 460 tons
Lightweight at 9 ft $2\frac{7}{8}$ dft. ...	27 218 tons
Gross tonnage	75 509·46 tons
Machinery output:	
m.c.r.	27 500 bhp at 98 rev/min
n.c.r.	25 000 shp at 95 rev/min
Trial speed	17·8 knots on 28 ft 0 in in draught
Service fully loaded	15·5 knots on 57 ft 1 in
Cargo capacity	6 056 000 ft^3
Endurance	26 000 sea miles

Two side-rolling hatches have been provided for each cargo hold. These hatches have been designed by the Kure Shipyard. Each cover is opened or closed by an hydraulic motor through high-tensile steel chain. There are two electric motor-driven hydraulic pumps, one acting as standby, for operating the hatch cover-handling motors and the hydraulic jacks for lifting up the covers.

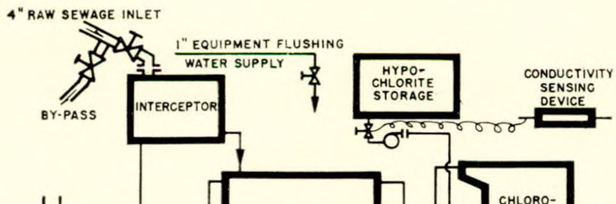
Universe Aztec is powered by a set of General Electric type cross compound, impulse type steam turbines of 25 000 shp output (n.c.r.) and 27 500 shp (m.c.r.), driving a five-bladed propeller of about 25·4 ft diameter at 95 rev/min, through double reduction double helical, tandem articulated type reduction gearing. The throttle steam pressure is 41·2 kg/cm^2g (585 lb/in^2g) and 457°C (855°F), with a steam rate at normal load of 2·71 kg/shp h (5·98 lb/shp h). The designed fuel consumption is about 241 gr/shp h (0·532 kg/shp h) based on fuel oil of 10 280 kcal/kg (18 500 Btu/lb) and the following conditions:

Main turbine output	2500 shp
Generator load	640 kW
Evaporator load	1125 kg/hr

Steam is generated in two IHI-Foster Wheeler 'D' type boilers at a superheater outlet pressure of 42·2 kg/cm^2g (600 lb/in^2g) and 463°C (865°F). The normal total evaporation of each boiler is 44·5 tons/h, and the maximum total evaporation 59 tons/h.—*Shipping World and Shipbuilder, January 1970, Vol. 163, pp. 151–152.*

Shipboard Sewage Unit

The Power Systems Division of Colt Industries has recently completed eight shipboard sewage treatment plants of advanced design for installation in U.S.S. *Canopus*. These compact units will make the U.S. Navy submarine tender completely self-sufficient in preventing harbour pollution from sewage system discharges. The cleansed liquid discharge from these units meets current official requirements for preservation of water quality. This equipment's advanced design is such that the technology of waste handling no longer depends on biological processes, whose effectiveness can be affected by heavy weather, and also eliminates the need for emptying holding tanks of refuse when the vessel docks. The Colt design is centred on reduction of waste to ash.



Shipboard sewage unit

Operating on electromechanical principles, the system disposes a clean, pathologically safe effluent, solids being eliminated by odourless combustion. Flushing water from the toilets first enters an interceptor which continuously separates out the coarse solids, thus removing the bulk of these before they are dissolved in the effluent. These coarse solids are then transferred by gravity to a transfer unit. Liquid effluent from the interceptor flows by gravity to the holding tank where the waste load and flow surges are balanced. Effluent is then supplied on a continuous basis from this holding tank to the chloroflotator where residual suspended solids are flotated and the liquid effluent is chlorinated. When operating with fresh water, a hypochlorite supply is required although this is not needed for operation in sea water which has an adequate chlorine supply always available. Sludge separated in the chloroflotator is mechanically fed to the previously mentioned transfer unit while the pathologically-safe effluent is fed to a sump tank for discharge overboard. Solids are mechanically fed from the transfer unit into an incinerator where they are reduced to a chemically and biologically inert ash, which is manually removed at periodic intervals.

The prototype of the system, developed under Navy contract was rigorously tested first at the Navy's laboratory in Annapolis, Maryland, and subsequently aboard the U.S. Navy destroyer *Fiske.—Shipbuilding International, March 1970, Vol. 12, pp. 24–25.*

Improvements of Linear Wear by Plasma-Arc Deposition

The use of various kinds of cast iron for the liners and rings of slow-speed Diesel engines does not reduce the rate of wear significantly, according to a report by B.S.R.A. However, the application of molybdenum by metal spraying into grooves machined in the liners can reduce liner wear to 40 per cent of that found in standard liners.

These conclusions were reached after an investigation into the influence on cylinder wear rates of cylinder liner and piston ring materials conducted on behalf of B.S.R.A. by Ricardo and Co. Ltd. During these tests a Crossley horizontal HH9 engine of $9\frac{1}{4}$ in bore and 16 in stroke was used in conjunction with a series of sand-cast iron liners coated with a variety of materials and using both transferred arc and oxy-acetylene deposition techniques.

The transferred-arc plasma process was successful in applying all the tested coatings adherently to cast iron, but defects were invariably present. In the Ni/tungsten-carbide coatings, which were investigated most intensively, the most obvious defects were pores.

Cracking of Ni/tungsten-carbide coatings was a less obvious defect than porosity. The experimental work indicated that the action of the transferred plasma arc caused cracking unless the cast iron was maintained at about 600°C during deposition. Preheating of cast iron is in fact a necessary feature of any fusion-welding process to enable the normally brittle cast iron to accommodate the thermal stresses set up. Even so, all attempts to apply a crack-free coating by the transferred arc plasma process to cast iron maintained at 600°C were unsuccessful. The coatings tried included:

Ni/tungsten carbide (50:50).
Co/tungsten carbide (50:50 and 70:30).
Ni/Mo (50:30).
Stellite SF6.

At least one of these coatings had already been applied without cracking to a 0·4 per cent carbon steel, which had not been preheated. The incidence of cracks in plasma-coated cast iron must therefore depend on some interaction between the coating and the cast iron. A possible reason is that all the graphite is taken into solution in the layer of melted cast iron. On cooling, both the coating and the cast iron resolidify and at some lower temperature regraphitization commences in the previously molten cast-iron layer. This process is accompanied by a considerable increase in volume which the coating is unable to accommodate and as a result it cracks.

This explanation will hold for all fusion methods of depositing coatings on to cast iron. Consequently a coating method, such as powder welding, which does not involve melting the cast iron is to be preferred. Even with powder welding, however, preheating of the cast iron is essential, and although a temperature of 400°C sufficed for depositing coatings of hardness 500 HV, coatings of 700 HV cracked under these conditions and a higher preheat temperature may be necessary.

The success of the powder-weld method lie in the formation of a diffusion, rather than a fusion, bond. Thus the surface layers of cast iron are heated and the constituents of the powder facilitate wetting the cast iron, so that diffusion alloying between the coating and substrate can take place. The results of the engine tests indicate that the wear resistance of Colmonoy 5, applied by the powder-welding process, was as good as that of molybdenum applied by metal spraying, but was more damaging to the cast-iron piston rings. Powder welding has the disadvantage of being a manual method requiring considerable skill and difficult to mechanize, and of requiring preheat if a bond more secure than that obtainable by metal spraying is required.—*Abercrombie, J. S. and Bidmead, G. F., The Motor Ship, January 1970, Vol. 50, pp. 484–486.*

Foam and Firefighting

A ship of 200 000–250 000 dwt moving at 16 knots or so creates an apparent head wind of eight miles per second (or Force 4/5) and in the event of a fire on deck or in a tank there will immediately be a stream of flames and extremely hot gases over the bridge and accommodation. In simulated tests (Malmö 1968) steel plate has been heated by such a stream of hot gases to about 800°C within two to five minutes. At this temperature the windows in the bridge front bulkhead will melt away, besides the effect on furnishings behind the bulkhead.

After the failure of the windows the temperature in the accommodation will immediately rise to intolerable levels and CO concentrations are also likely to be fatal. The crew will therefore be incapacitated before there is any chance of stopping the ship (which will take perhaps 20 minutes) or altering course to bring the wind, if any, astern.

The answer is to spray immediately with water the entire bridge front at a rate something like 20 gal/min/100ft^2 of surface area, keep it cool until the ship can be stopped or turned. The existing deck monitors, if parked facing the bridge and fitted with appropriate nozzles, would do the job nicely. Fixed spray nozzles over the bridge front would do even better, and could be fed through internal pipes. Norske Veritas and other bodies are in fact now acting in this respect.

Conventional "heavy" or low-expansion foam has an expansion factor of five to ten, i.e., the liquid is expanded to between five and ten times its original volume. Medium-expansion foam has an expansion factor of 50–400, while high-expansion foam is generally considered to be foam with an expansion factor of 500–1000.

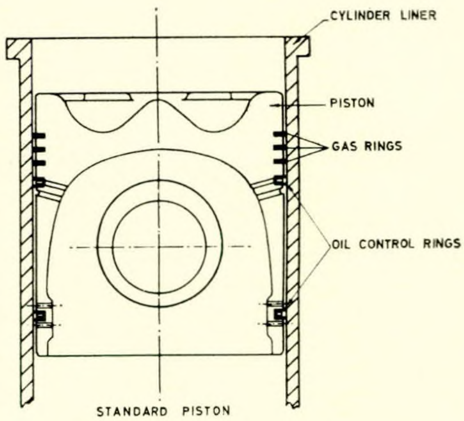
High-expansion foam is generated by blowing a stream of air past a mesh wetted by a water/foam agent mixture, with an effect similar to that of our childhood soap-bubble blowing efforts. The heavier types of foam are produced in aspirating branch pipes. However, it should be borne in mind that some writers refer to "heavy" foams with an expansion factor of, say, seven as "froth" and to all lighter foams as "high-expansion". Though this is incorrect, there is in fact one important disadvantage that distinguishes the low-expansion types from medium and high-expansion foams: heavy foam falling freely onto a burning oil surface in flows exceeding 60 l/min is liable to dive beneath the surface and on re-emerging it will entrain burning oil. This phenomenon, known as "pick-up", results in a burning froth instead of the desired extinguishing effect.

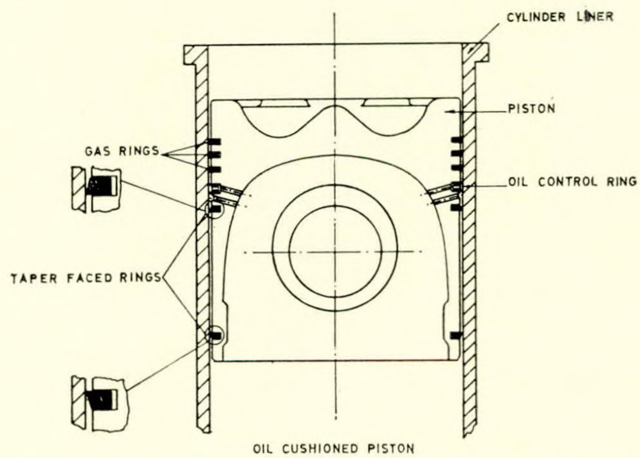
An advantage of high-ex foam which is not always appreciated by shipowners, but which is of considerable psychological importance, is the ease of testing the firefighting equipment. Anyone who has undergone a naval damage control course will be aware of the difference in attitude towards apparently catastrophic situations before and after one has actually seen and used the available equipment in action.

It is almost impossible to demonstrate to a crew the efficiency of a CO_2 installation, and certainly not in complete safety. But it is a very simple matter to demonstrate a high-ex foam outfit in a most visible and convincing manner—and even, with a little imagination, to arrange a realistic exercise. It is common practice to provide a deck outlet for test purposes.—*Irons, G., Marine Engineer and Naval Architect, March 1970, Vol. 93, pp. 124–128.*

Patented Oil Cushioned Piston

Most efforts to counter the waterside attack on cylinder liners known as cavitation corrosion consist of treating the external surfaces with special paints, ceramics or sprayed glass fibre filler. These methods are, however, at best, palliatives—remedies for the symptoms and not the cause. It has been made adequately clear that the cavitation which does the damage is due to the high frequency vibration exerted in the liner by the lateral blow struck by the piston in taking up its clearance under the influence of combustion and the obliquity of the connecting rod. The first impact is taken by the bottom of the skirt due to piston tilt and this is followed almost immediately by a second impact when the crown of the piston strikes the liner.





Ring arrangements on standard and oil cushioned pistons

Work carried out at Admiralty Research Laboratory has shown that by arranging a downward-passing scraper ring above the gudgeon pin and an upward scraper at the bottom of the piston skirt it is possible to build up a high pressure oil belt between these rings. This high pressure oil belt takes several minutes to reach its working pressure of 150/200 lb/

in², from start-up, but thereafter acts as an oil cushion or damper and considerably reduces the incidence of piston tilt and slap and also the normally irregular motion of the piston down the bore of the cylinder.

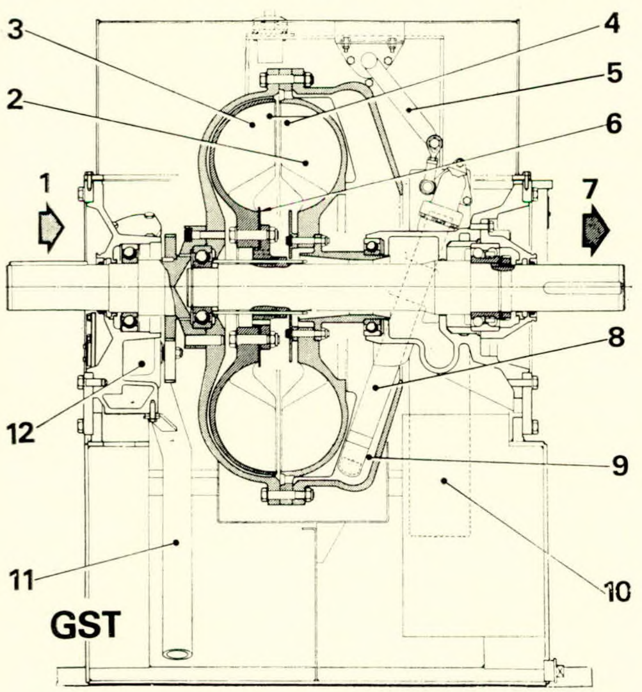
Experiments were carried out at AEL on a 9¾ in bore, single-cylinder four-stroke Diesel. During a total of 2000 hours running on this unit it became apparent that in addition to the reduction of waterside attack other advantages were obtained. It was found, for example, that piston ring and cylinder wear are considerably reduced and that, furthermore, the presence of a continuous circumferential oilbelt acts as an excellent gas seal and eliminates blow-by into the crankcase. Improved piston cleanliness and extended oil life result.

The oil-cushioned pistons offer the possibility of reducing oil consumption without increasing the risk of piston seizure, a very real danger with very highly rated engines. Tests have shown that it is possible to reduce oil consumption to the low figure of 0·3 per cent of fuel input. The cushioning effect substantially reduces the noise level of the engine by the elimination of piston slap.

More recent work includes the fitting of a complete set of oil-cushioned pistons to two 9¾ in bore turbocharged six-cylinder in-line Diesel engines. In the first instance 2000 hours were completed satisfactorily on a test bed installation. A further set has been fitted into a similar engine aboard H.M.S. *Vidal*. To date this engine has completed over 3600 hours without incident.—*Marine Engineer and Naval Architect, January 1970, Vol. 93, p. 17.*

Fluid Couplings

Fluidrive Engineering Co. Ltd. has developed a new range of variable speed fluid couplings. Designated type GST, the units are available in five versions for coupling machinery to motors from 600 hp to 3300 hp at operation speeds up to 3000 rev/min or powers from 800 hp to 2900 hp at 3600 rev/min. With four pole motors the power range covered is 1650 hp at 1500 rev/min or 1400 hp at 1800 rev/min. Speed variation of the output is infinitely variable within a guaranteed range of 5:1 and is often greater, depending on the application.



1) Input
2) Impeller
3) Runner
4) Working circuit
5) Control lever
6) Baffle
7) Output
8) Scoop tube
9) Scoop chamber
10) Oil reservoir
11) Suction pipe
12) Oil circulating pump

GST type hydraulic coupling

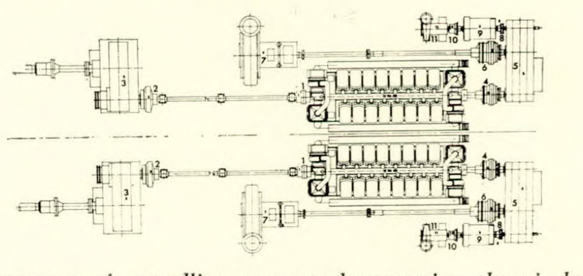
While many new design details are incorporated, the basic principle of the fluid drive remains unchanged, transmission of the motive power being gradual and shockless through the kinetic energy of oil flowing between the input and output elements of the coupling. The coupling itself comprises two face-to-face rotating elements with multi-radial vanes encased in oil. One of these elements, the impeller, is driven by the input shaft and behaves like a centrifugal pump creating an outward flow of oil. This oil crosses the gap to the other element, the runner, which acts as a turbine. Rotary propulsion is transmitted to the runner as the oil is forced between its vanes and returns to the impeller to repeat the cycle.

The constant speed traction coupling holds a measured quantity of oil, this quantity precisely determining the protection against overload or stalling. Start-up time can be reduced on heavy or rotationally inert machinery as the motor is free to run at near peak output, developing up to twice full-load torque for rapid acceleration as its power is gradually absorbed and transmitted by the hydraulic coupling. This load reduction greatly cuts current consumption and allows use of squirrel cage motors for applications normally needing more sophisticated and costly motors.—*Shipbuilding International, February 1970 Vol. 12, pp. 40, 41.*

Combined Dredging and Propelling Plant

The greatly improved mechanical transmissions which have become available in the past decade and the confidence which they have given to their operators has resulted in the adoption of all-gear drives for installations where electrical drive would have been the only choice some years ago.

In a large dredger building at Smits of Kinderdijk for the Anglo-Dutch Dredging Co. and powered by two 16-cylinder Werkspoor 16TM410 non-reversible engines, full power can be taken from the front of the engine thus avoiding the need for complicated gear-boxes and large clutches in the secondary shaft, to permit disengagement of the propeller from the gearing.



Arrangement of propelling pump and generating plant in large Anglo-Dutch dredger

Each engine drives, from its flywheel end, an Escher Wyss controllable pitch propeller. Transmission is through a long drive shaft with a Bogenzahn coupling immediately aft of the flywheel and a Planox clutch immediately forward of the simple parallel-shaft Jahnel reduction gears. The long drive shaft running at engine speed permits this to be much smaller and more flexible than would be the case with a low-speed shaft and the Planox coupling accommodates variations in length due to expansion.

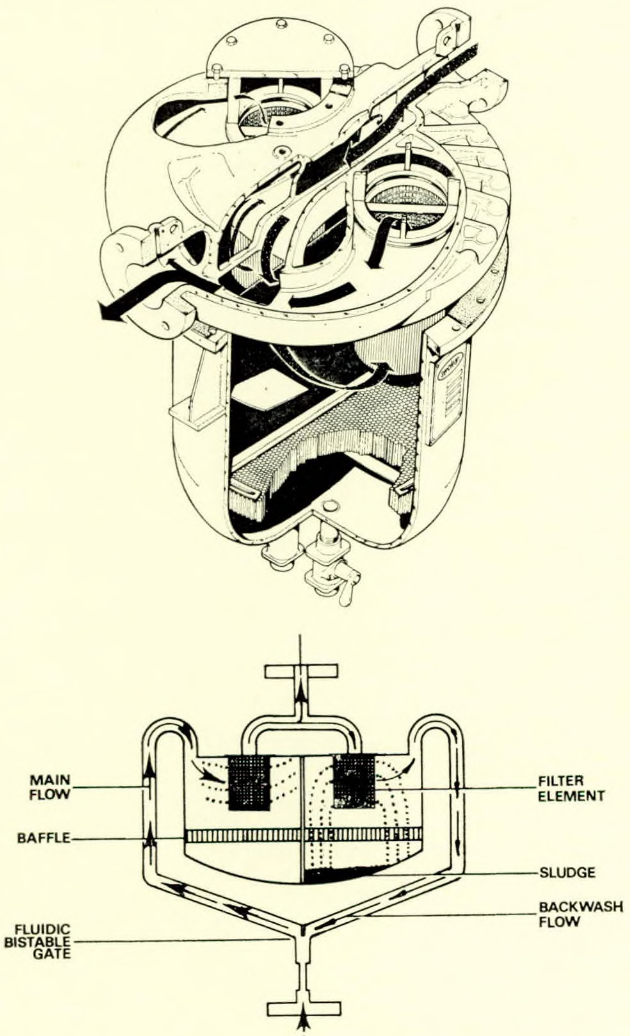
At the forward end of the engine a Lohmann and Stolterfoht Pneumaflex highly-elastic coupling with integral air-operated clutch is fitted between the engine crankshaft extension and the pinion. The Jahnel three-shaft gear-boxes (5) provide a drive to the dredging sand pump (7) through a second Pneumaflex clutch (6) while a third gear in the box drives through a Holset elastic coupling (8) a ship's service generator (9) and in tandem, through yet another Planox clutch (10), a flushing water pump.

The two engines are rated 8000 bhp at 500 rev/min corresponding to a b.m.e.p. of 14·5 kg/cm with a maximum rating of 8800 bhp. The reduction gears (3) provide a constant propeller speed of 150 rev/min. The reduction gear (5) provides output speeds of 180 rev/min for the 2600 hp dredging sand pump (7) and at 1200 rev/min on the outer lay shafts for the 1100 hp flushing water pumps and the 1000 kVA 60 hz alternators. When sailing out to the dredging grounds the clutch to the gear-box forward of the engine is disengaged and the whole available engine power can be applied to propulsion but when dredging the pumps and generators are all driven by the engine.—*Marine Engineer and Naval Architect, February 1970, Vol. 93, p. 67.*

Automatic Filter Cleaning Controlled by Fluidics

Research engineers of the Serck Group have applied fluidics to the operation of a self-cleaning strainer which has no moving parts and which requires neither power supply nor manual operation.

Two identical flow paths each contain a filter element and a fluidic bi-stable gate is arranged to switch the liquid flow to a clean element as soon as the working side becomes partially clogged. A constant stream of clean filtrate then passes in reverse direction through the stand-by element, to wash off contaminate, and collect it for later removal.



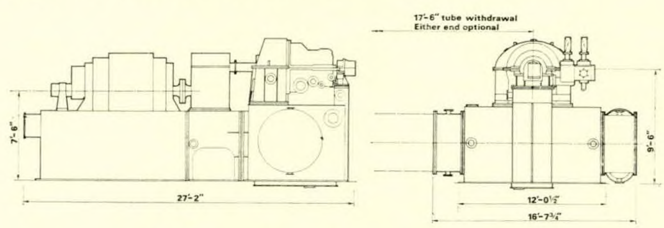
Serck fluidics-controlled strainer, with below, a sketch showing the working principle

These Serclean strainers are designed for liquid/solid separation, and are particularly suitable for straining water or low viscosity fluids for process or cooling applications. Standard filtering element apertures down to 0·016 in are available and separation levels as low as 100 microns can be achieved under acceptable conditions. The design offers the advantage of a constant working pressure-drop. Lengthy site trials have been carried out and the unit is now offered in a range of sizes suitable for flow rates from 25–200 gal/min.—*Marine Engineer and Naval Architect, January, 1970, Vol. 93, p. 46.*

Geared Propulsion Alternators for Second Rangatira

The twin screw turbo-electric passenger and vehicle ferry which the Union Steamship Co. of New Zealand has ordered from Swan Hunter Shipbuilders Ltd. as a replacement for the short-lived *Wahine* will carry slightly fewer passengers than her predecessor, but the same number of cars, on the North/South Island service between Wellington and Lyttleton. The new ship is to be *Rangatira*, the name carried by the Vickers-built vessel of 1931, at a period when a number of electrically-propelled ships were delivered.

The new *Rangatira* will have more powerful machinery, developing 20 500 shp as against the 18 000 shp of *Wahine*. Of particular significance is the use of geared turbo alternators for propulsion machinery of substantial power. English-Electric-AEI Turbine Generators Ltd. will provide the turbines and gearing and English-Electric Machines Ltd. will be responsible for the electrical side of the installation.



7·9MW geared propulsion turbo-alternator

They will conform to EE-AEI standard practice for condensing marine turbo-generators. The single cylinder is supported upon its transversely-tubed condenser which is solidly bolted to a stiff oil drain tank/bedplate which also supports the gearcase. This bedplate is bolted to the generator bedplate, forming a strong, compact unit. The turbines operate with steam conditions of 560 lb/in^2, 830°F and when operating at the economical load of 7000 shp the vacuum will be 28 in Hg. Steam admission is through a separate steam chest bolted to the bottom half of the hp cylinder and then through welded-in nozzle boxes which protect the cylinder from the maximum pressure and temperature of the steam and restrict temperature fluctuations of the casing. The maximum cylinder temperature will be approximately 200°F below that of the incoming steam. Speed control is by a Woodward sensitive oil governor, and EE-AEI actuators for the nozzle group valves. The solid forged gashed rotor has a two-row velocity compounded stage followed by ten impulse stages and runs at a maximum speed of 6300 rev/min. Stainless steel blades are secured to the rims by the makers' standard circumferential fastenings. The diaphragms are welded in the hp section of the turbine and of cast iron in the lp section. The usual safeguards against overspeed, loss of vacuum, falling oil pressures, etc. are provided. Thermocouples enable oil temperatures and similar quantities to be read from the instrument panel.

The drive to the generators is through top-pinion double-helical single-reduction gears supplied by Modern Wheel Drive Ltd. (Rugby). The gearcase is carried directly over the oil tank/bedplate and contains a nitrided pinion meshing with a through-hardened wheel of fabricated construction.

The alternators supply current to a pair of double-unit forced-ventilated synchronous induction motors rated 10 250 shp at 231 rev/min. These motors are also of salient pole type and have squirrel cage starting windings incorporated in the rotor pole faces. Each comprises a single frame containing two electrically separate machines, the two rotors being mounted on a single shaft by self-lubricated bearings incorporated in the end shields. The motor-driven ventilation fans draw air from the compartment, deliver it through the motors and discharge it back into the compartment through sea water circulated coolers.—*Marine Engineer and Naval Architect, February 1970, Vol. 93, pp. 109–110.*

Machinery and Equipment for the SD-14 Liberty Replacement Ships

The first ships of the series were completed in early February, 1968, and 18 have been completed for 11 different owners from the Wear Shipyards of Bartram and Sons Ltd., and Austin and Pickersgill Ltd. The basic SD14 design included the installation of three 170-kW Diesel-driven alternators. The introduction of additional equipment chosen from the list of optional items, has resulted in a higher base load in all the SD14 vessels than was originally planned. This resulted in an eventual change in builders' specification to include three English Electric (Paxman) 6RPHXZ 1200-rev/min Diesel engines coupled to 218-kW MacFarlane brushless alternators. A typical electrical loading schedule includes a normal sea load of 153 kW with a Part II intermittent sea load of 45 kW. The manoeuvring load is 285 kW, with two alternator sets in service, and a port load of 290 kW, again with two alternators in service.

Inevitably, with continual improvements and modifications being carried out independently by the designers and manufacturers of marine engines, auxiliaries and equipment the original SD14 machinery installation must reach the stage when reappraisal is necessary. A suitable stage has now been reached with the introduction of the RND type Sulzer engine.

Ancillary machinery required for the higher powered main engine has resulted in an increase in the basic electrical loading. The revised loading schedule indicated a normal sea load of 189 kW, with a Part II intermittent sea load of 64 kW. Electrical manoeuvring load is expected to be about 360 kW and a port loading of 398 kW. The electrical plant to meet these requirements consists, basically, of three 280 kW MacFarlane a.c. generators at 440 volts, three-phase, 60-cycles. Each machine is driven at 1200 rev/min by a Paxman 6 RPHCZ type engine rated at 409 bhp. One alternator will be in use at sea, with two in operation under manoeuvring or port conditions, with deck machinery in use.—*The Motor Ship, January 1970, Vol. 50, pp. 495–497.*

Radar Clutter Reduction Techniques

Moving Target Indication (M.T.I.) is a technique applied in pulse radar systems for the reduction of stationary or slowly moving echoes. Some echoes come under the general heading of clutter and their presence tends to mask and confuse the detection of moving targets with search and surveillance radars.

The main feature distinguishing fixed and moving targets is the Doppler frequency shift associated with the latter and thus various filtering methods can be used to discriminate between the two. The filtering associated with M.T.I. systems is in the form of a comb filter, giving a rejection region for each spectral line of the radar pulse's frequency spectrum; with a moving target, the spectrum shifts out of the rejection notches and thus an output is obtained from the filter. Such filtering methods make it possible to detect a moving target which is much smaller than the overlaying clutter signal, i.e. one achieves a high level of sub-clutter visibility.

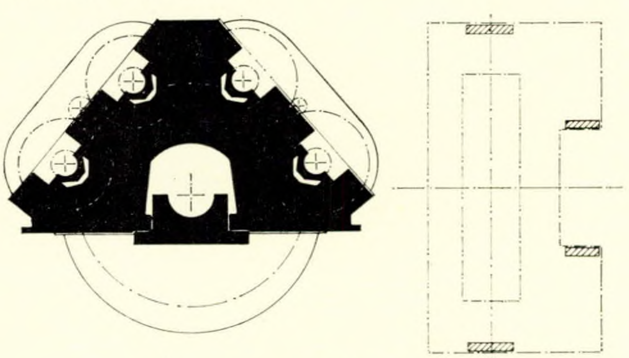
In practice, an M.T.I. system measures the radio frequency carrier phase angle of received echoes after each radar transmission. Those echoes which do not change phase from one transmission to the next are stationary echoes, whereas for a moving target the echo phase is changing from pulse to pulse by an amount determined by the target's radial velocity with respect to the radar; thus it can be appreciated that what is needed is a system comprizing some form of store, or memory, to remember the phase of a target echo until the next echo from the same target is received; then, some form of subtractor is needed which gives an output for echoes which change in phase from pulse to pulse, i.e. moving target, and which gives no output for steady phase targets, i.e. clutter. This combination of memory and subtractor is generally known as an "M.T.I. Canceller".

At the Admiralty Surface Weapons Establishment at Portsdown (A.S.W.E.), investigation of commercial M.T.I. cancellers was proceeding some two years ago for shipborne radar systems, and it was then appreciated that digital methods would eventually replace the quartz line cancellers. Work began in early 1968 on the development of digital cancellers, the initial aims being to demonstrate a canceller system with operational characteristics similar to those of the classic type canceller, and to investigate and develop suitable electronic circuits and components for the next generation of radar equipments.

The first digital M.T.I. model was completed early in 1969 and has been operating in commissioning tests and with two separate radars at A.S.W.E. This model was the first of its type working in the U.K.—*Shipping World and Shipbuilder, March 1970, Vol. 163, pp. 450–453.*

New Gear Case Design

In the ever increasing search for more compact designs of turbine machinery and improved efficiency, a new look at established technology has resulted in a new concept of structural design for gearcases that, in its very simplicity, is an outstanding step forward.



EE-AEI single-piece gearcase

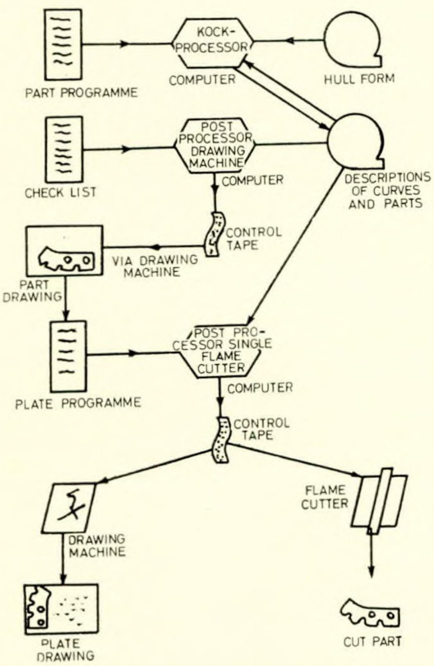
This new casing design will be adopted for the 40 000 shp machinery being supplied by English Electric-AEI Turbine Generators Ltd. for the twin-screw Ben Line container ships on order with Howaldtswerke-Deutsche Werft, Hamburg.

The covers are reduced to a minimum and most are of very light construction. The gearcase is supported on four areas. As shown in the diagram, two areas, at the sides in line with the second reduction gears, take most of the weight and the torque reaction. The other two are forward to act as a steady support and take the overhung weight of the primary gears. The height of these supports, close under the shaft centre line, allows the development of a very strong and rigid turbine/gearing/thrust seating which helps to prevent misalignment of gearing from external sources causing hull distortion.

A range of single-input gearcases has been drawn up using the same principle of a single-piece fabricated structure and the idea has been extended to cover triple-reduction gearboxes to meet the future requirements for very low propeller speeds in twin-screw tanker applications.—*Young, I. T., Marine Engineer and Naval Architect, February 1970, Vol. 93, pp. 100–103.*

Computerized Ship Design

The need for increased production and greater accuracy in design, materials ordering, and production of parts, coupled with a general shortage of labour are problems which face most of the larger shipyards today. One answer to all of these problems, and possibly the only one in the long-term view, is the use of a central computer system coupled with numerically controlled drawing machines and machine tools—this has been taken up in varying degrees by many of the world's leading shipbuilders.



Computerized ship design—Flow of information

Thus, in conjunction with Saab A/B, Kockums has developed a numerical system, named Styrbjörn, such that a relatively integrated system of computer programmes has been built up, containing among other things, post processors for a drawing machine and two- and three-axis flame cutters. The Kock language gives the designer a means to use the computer and the drawing machine for calculations, product and part descriptions, and graphical representation. These activities can be integrated and the resulting part descriptions, on magnetic tape, can be directly used by the computer to produce—with the aid of the post processors—paper tapes for directing the flame cutters.

With the Styrbjörn system the following activities can be performed:

1) Fairing of ship hulls or other three-dimensional surfaces. The resulting numerically defined form curves are stored on magnetic tape for further use.
2) Automatic drawing of the form information.
3) Development of double-bend shell plates and producing paper tapes for drawing and cutting. In the development process the form is taken from magnetic tape.
4) Producing paper tapes for drawing and cutting inner hull parts with the computer working according to Kock programmes. These can either describe the designed parts or include one or more of the design activities. In the Kock programme it is possible to use the form curves stored on magnetic tape.
5) Calculations such as hydrostatical data, stability and so on.
6) Producing information for material ordering, costing and similar functions.
7) Producing steelwork drawing from the classification drawings.

The Motor Ship, February, 1970, Vol. 50, Marine Automation Section, pp. 11; 13.

Germany's Largest Marine Diesel Engine

The largest and most powerful marine Diesel engine yet built in Germany recently completed testbed trials at the Essen works of Fried. Krupp Industriebau und Maschinenfabriken. This a Burmeister and Wain eight-cylinder unit of the K98FF super-large-bore type with a maximum continuous rating of 30 400 bhp at 103 rev/min and is now being installed in a 150 000 dwt OBO ship under construction at A.G. Weser.

Building for Wilhelm Wilhelmsen, of Oslo, the vessel is designed to have a trial speed of 16·2 knots when the engine is developing 28 000 bhp at 100 rev/min. On test, at this speed, the mean effective pressure was 10·34 atm and m.i.p. 11·35 atm, with a specific fuel consumption of 152 g/bhp h.

Control of the engine is through a B. and W. pneumatically operated system with facilities for bridge control. The system includes a Woodward governor equipped with a scavenge air-operated load limit device, and control of both speed and loading is incorporated. To facilitate maintenance, a full outfit of hydraulically operated tools are provided. These will deal with the studs and bolts for the main, bottom-end and crosshead bearings, piston rod nuts, tie rods, exhaust valve studs and camshell bearing studs. The triple camshaft drive chains are also hydraulically tensioned.—*The Motor Ship, January 1970, Vol. 50, p. 505.*

Explosions in Tankers

Pending the findings of the major oil companies as to the reasons for the explosions in the giant oil tankers *Marpessa, Mactra* and *Kong Haakon VII*, a mass of possibilities have been put forward by experts and others, which vary from phenomena due to the ships' position at sea when the disaster occurred, to the generation of static electricity in clouds of spray which have formed while using tank cleaning machines. Of the many reasons suggested it could well be that the build-up of static electricity is the most probable. Whatever the causes are, there remains the question whether it could have been prevented.

There are tanker owners who strongly favour the use of inert gas, with which the cargo tanks are completely filled so as to prevent an explosion, should a static spark occur. But this method is only safe if the tanks are completely filled with the gas. Inert gas can be obtained from extracting gases from the main or auxiliary boiler flues, but in order to obtain the correct content of inert gas from the auxiliary boilers in a motor ship more fuel oil than usual is burned, and this increases the running costs. This article gives a short survey of what has happened to tankers in the past in the way of mishaps, and outlines some of the inert-gas systems employed and equipment used for tank cleaning and gas dispersal.—*Shipping World and Shipbuilder, March 1970, Vol. 163, pp. 421–424.*

Blade Failures in the H.P. Turbines of R.M.S. Queen Elizabeth 2 and their Rectification

The H.P. turbines of *Queen Elizabeth* 2 both suffered from blade failures on the proving voyage prior to acceptance by the owners.

The failures were recognized to be due to fatigue and investigations took place to establish the cause.

The paper records the history of the operation of the engines up to the time of failure, which had included trials up to full power of 110 000 shp, and reports on the damage sustained.

It reviews the blade vibration aspects, establishing the theoretical background and discussing the response to external and steam excitation.

The determination of the blade frequencies in the affected stages on the basis of past research and recent measurements in the laboratory on groups of blades is treated at some length and it is deduced that one or other of these stages would reach a state of resonance with the nozzle wake impulse frequency within the range from half shaft speed to full speed. The particular modes of vibration are tangential batch modes known as "clamped-pinned".

It is concluded that such vibration is the prime cause of failure, aggravated by stress concentrations. The rectification of the fault by a redesign, incorporating a binding wire, is described.—*Fleeting, R. and Coats, R., Transactions of the Institute of Marine Engineers, February, 1970, Vol. 82, pp. 49–74.*

Bulk Carrier with Self-unloading Gear

The Caribbean Steamship Company S.A., a subsidiary of Reynolds Metal Company, of Richmond, Virginia, has taken delivery of a bulk-carrier specially designed for the transport of bauxite. This vessel, *David P. Reynolds*, 48 970 dwt has self-unloading equipment and is the largest of this type yet constructed.

Principal particulars are:

Length, o.a.	223·95 m
Length, b.p.	213·36 m
Breadth, moulded	31·09 m
Draught, designed...	12·19 m
Deadweight	48 970 tons
Draught, maximum	12·79 m
Deadweight	52 450 tons
Gross tonnage	28 000
Machinery	18 000 shp
output	at 85 rev/min
Speed, 12·19 m draught	17·8 knots

To remove manoeuvrability when coming alongside or casting off, and when passing through lock gates, a KaMeWa bow-thrust unit powered by a 1200 hp (M) motor and having controllable-pitch propeller blades has been fitted.

The self-unloading plant comprises several conveyors, which receive the ore from under the holds and carry it to the after end of the ship; the boom conveyor then discharges it to a shore receiving conveyor system. The cargo holds slope downwards to a number of small chutes, each of which can be closed by a gate, actuated hydraulically, with a four-position valve to give the desired discharge rate.

The propelling machinery is of the conventional type with two boilers and a main turbine plant with three extraction stages of which the H.P. bleed serves the auxiliary systems (heating etc.), the L.P. bleed and some on the crossover line serves the supply to the deaerator, while the one on the L.P. casing has been provided for the one feed water heater and the sea water evaporator. The exhaust steam from the turbine-driven feed pump feeds the air heater, a small portion also being passed to the deaerator. The turbine-driven alternators have separate condensers. The specific consumption of this plant amounts to 226 g/shp-h (approximately).

Steam is generated in two integral furnace boilers of 27·7 t/h normal evaporation and 36·6 t/h maximum evaporation at 61·5 atmospheric pressure/499°C at the superheater outlet, built under Babcock-Wilson licence. The attemperator is housed in the upper drum, while the desuperheater for make-up steam and for the supply to the injectors is fitted in the lower drum. The boilers are for lateral firing. *Shipping World and Shipbuilder, February, 1970, Vol. 163, pp. 299–302.*

The "Clyde" Design

A new design of vessel of the general purpose type, with features similar to those of the Liberty replacement type of ship, has been introduced by Upper Clyde Shipbuilders Ltd. The so-called "Clyde" design cannot be considered as being directly comparable with Liberty replacements however as it has a greater capacity and versatility. The new type of ship has been developed as a general cargo carrier suitable for efficient operation when carrying lengthy and heavy cargoes, timber, grain, ore, general cargo and containers.

It is claimed that the Clyde type of vessel has the advantages of larger cubic capacity, greater deadweight, higher speed, larger hatches and better cargo handling gear than any existing ship of broadly similar design. It is intended that the vessel be built for classification by Lloyd's Register ✠ 100A1 "heavy cargoes" 1965 grain cargo regulations for the common loading of holds and 'tweendecks, and to British Board of Trade regulations and British Suez and Panama tonnage rules.

This is a single-screw Diesel-engined ship of all-welded construction, having accommodation, in a five-tier deckhouse, and machinery all aft. There is a raked stem, transom stern and Simplex rudder. Six watertight bulkheads divide the hull into a fore peak tank, four cargo holds, engine room and after peak tank. There is a second deck throughout the cargo space which gives a 'tweendeck to the holds. No. 3 hold below this 'tweendeck is divided transversely to give a floodable forward hold, and an aft hold. No. 1 hold is also suitable for partial flooding.

Propelling machinery selected for the Clyde design is a Sulzer 5 RND 68 two-stroke turbocharged and inter-cooled Diesel engine arranged for running on Diesel fuel or heavy fuels up to a viscosity of 3500 secs Redwood No. 1 at 100°F. The engine is derated by 10 per cent from the designers maximum continuous rating as a service allowance. This means that the output at m.c.r. of 8250 shp (M) at 150 rev/min is rated in service as being 7400 shp (M) at 145 rev/min. Fuel consumption is estimated as being about 28·5 tons/day at service power, and the range with 870 tons of fuel oil is of the order of 10 000 miles. The speed at the design draught of 28 ft 0 in (8·53 m) at the engine's normal service output with no service allowance is 15·4 knots.—*Shipping World and Shipbuilder, February, 1970, Vol. 163, pp. 309–310.*

The Application of Helicopters to Marine Services

The aim in presenting this paper has been to make marine operators aware of the capabilities, limitations and cost of current and future helicopters; shipborne facilities required to enable helicopters to be used in marine work and indicate certain areas where helicopter participation may prove to be a viable proposition.

A secondary aim is to indicate procedures in which routine operations may be conducted with due regard to safety considerations for both passengers and third party interests. The word "routine" is stressed, as, in the context of single engined helicopter operations, that which it is entirely safe to do once off in an emergency, cannot be considered safe for long term routine operations as, inevitably, the probabilities of a failure become significant and unless procedures are laid down to take account of this there can be considerable danger to individuals, helicopters and vessels alike.—*Gordon, A. C., Transactions, The Institute of Marine Engineers, March, 1970, Vol. 82, pp. 97–106.*

Oil Sales Barge

An unusual craft recently completed by Thames Launch Ltd. is the 56 ft sales barge *Osupa-Do* for Shell Nigeria. Built to the design, and under the supervision of Shell International Marine, the craft will serve on the Niger Delta in Nigeria where it will supply petroleum spirit and kerosene to the settlements on the Delta.

Principal particulars are:

Length, o.a.	56 ft 0 in
Length, w.l.	50 ft 0 in
Breadth moulded	13 ft 6 in
Depth moulded	4 ft 8 in
Draught	3 ft 5 in
Gross	24·98 tons
Cargo capacity	25 tons

The craft has three tanks for petroleum spirit totalling 4000 gal and two tanks totalling 2240 gal for kerosene. The cargo is discharged by means of Globe Pneumatic air-driven pumps through Avery Hardoll Bulkmeters and 60 ft hose reels with gun nozzles. A Petter type R140 rotary air compressor supplies air to the cargo pumps, the compressor being belt-driven *via* an Anderton clutch unit fitted to the port engine. Propulsion is by two Thornycroft 240 marine Diesel engines of 50 bhp at 1750 rev/min each coupled to a Bruntons propeller *via* Self Changing Gear-boxes of 3:1 ratio. Each engine is fitted with an AC5 alternator for battery charging, the electrics being carried out by Cox Electrodiesel Ltd. and were carefully engineered because of the type of vessel.

For fire and bilge pumping duties the craft has two Jabsco 1½ in dia. units, belt-driven, one from each engine *via* clutches.—*Shipbuilding International, February, 1970, Vol. 10, p. 13.*

Offshore Crewboat

Equitable Equipment Company Inc. of New Orleans has recently delivered the 100 ft offshore water taxi *Eagle* to the Arabian Gulf Mechanical Service and Contracting Company Ltd. of Kuwait.

The craft differs from conventional offshore water taxis in several respects, the most obvious of which are two fire stations and three 2½ in fire monitors each rated at 365 gal/min.

Two of the monitors are located on top of the main passenger cabin, port and starboard, and one on top of the forward cabin. They each have 360 degree clear travel and are equipped with nozzles suitable for discharging foam from a 250 gal foam tank. An independent Diesel engine-driven fire pump in the engine-room discharges to the three monitors at approximately 1100 gal/min.

Eagle has overall dimensions of 100 ft in length, a 21 ft beam, and a draught of 6 ft. Primary power comes from two Caterpillar D348TA Diesel engines of 1500 hp giving the boat a top speed of about 19 knots, while electric power requirements are met by two 35 kW 50 c/s a.c. generators.

Classed by the American Bureau of Shipping and built to the requirements of the USCG for carrying passengers for hire or as a combination passenger for hire-cargo vessel, *Eagle* will be based at Ra's al Khafji and operate in the Arabian Gulf. It has crew accommodation for eight men and an all-electric galley equipped with countertop electric range and oven, electric refrigerator and deep freeze. A cargo hold aft has a 620 ft^3 capacity, and the boat will carry 1500 gal of potable water. Accommodation for 30 passengers is arranged in a midship cabin. The vessel is air-conditioned throughout and carries radar equipment, fathometer, two ship-to-shore radios and is also equipped with an 11 in Kent Clearview Screen on the centre line of the pilothouse windshield.—*Shipbuilding International, March, 1970, Vol. 12, p. 14.*

Expansion of Black Sea Fleet

The Soviet Union's first comprehensively automated motorship, *Svetlogorsk*, has been built in Kherson, Ukraine. After a thorough check of the remote-control system, the ship is to be handed over to the Black Sea Shipping Administration which this year is to receive bulk carriers with a deadweight of 12 000 to 23 000 tons each. The ships are to be supplied by Soviet and Polish yards.

In the past decade the number of the Administration's ships has doubled while the total deadweight of the local merchant marine has more than quadrupled to reach two million tons. This has enabled the Administration to expand considerably its foreign trade carriage. At present, ships of the Black Sea Administration deliver cargoes to ports of 70 countries.

Last year the Black Sea-Canada Service was added to the permanent sea routes linking Odessa and Ilyichevsk with Bulgaria, Vietnam, Cuba, India, Middle East countries and Japan. Vessels operating on the new route, which are ice-breaking motorships, call at West European ports to pick up cargoes for delivery to Canada.—*Shipbuilding International, March, 1970, Vol. 12, p. 12.*

Jumboized Oiler for U.S. Navy

The jumboized Navy oiler, *Caloosahatchee*, was recently delivered to the U.S. Navy by Bethlehem Steel Corporation's Key Highway yard. It is the second of two Navy oilers to be jumboized by the yard. The vessel was lengthened by 91 ft to 644 ft by insertion of a new 395 ft 2 in midbody built at Bethlehem's Sparrow Point yard.

In addition to the new midbody, *Caloosahatchee* was equipped with twin rudders of high-strength steel which are operated by dual steering systems and a hydraulically operated helicopter pickup platform.

The bow and stern sections from the old ship were modernized and retained. The new midbody contains cargo tanks for fuel oil, JP-5, aviation gas and Diesel oil. There are large dry cargo storage spaces, refrigerated cargo spaces, an auxiliary machinery room, an aviation gas pump room and a fuel oil and JP-5 pump room. Ammunition and missile storage spaces have also been provided.

Three new elevators were installed in the midbody, as well as replenishment-at-sea gear which permits transfer of any of the liquid cargo, missiles, missile booster, warheads or miscellaneous cargo ships while at sea.

Major electrical changes included three 1500 kilowatt Diesel generators and outfitting for replenishment-at-sea gear and two 750 kilowatt turbo generators for ship's service. The existing electrical system was converted to a 440-volt system.—*Marine Engineering/Log, November, 1969, Vol. 74, p. 90.*

Automation Factors Influence Investment Return

Automation when applied to ships' systems is a misnomer, and it is true to say that ships nowadays are no more "automated" in the correct sense of the word than they were 15 or 20 years ago. All that has been done is to replace the Bourdon tube gauge or glass thermometer with electrical instruments, to muster the dials into a congested console, and to replace the direct manual controls adjacent to machinery with remote controls clustered in the same congested console. True, the electrical instruments make it easier to generate signals when values exceed or fall below preset levels and also enables a typewriter to print out these values. Thus the engineer officer of the watch can in theory now stand his watch in his bunk and the owner gets a typewritten engine-room register.

A jaundiced and cynical view, perhaps, but what a glorious opportunity has been missed by the industry which has a galaxy of modern techniques at its command and yet contents itself with bell-crank and lever methods.

This raises the question of whether the shipowner is getting value for money. In terms of hardware, software and labour the answer is probably yes. In terms of return on investment the answer can only be no, the task of assessing the value to the owner being one for the accountants, thereby leaving engineering personnel free to concentrate on their part of the ship.

Many factors should be taken into account such as:

i) Savings in the number of crew members (alternatively attracting crew by the allegedly less onerous duties in an "automated" ship).
ii) The cost of the "automation installation".
iii) The cost of ownership, maintenance, spares etc.
iv) The value to be obtained from continuous recording for machinery maintenance diagnosis.
v) Projected period of ownership.
vi) Any alteration in insurance rates directly attributable to "automation".
vii) Benefits due to optimizing passage length (i.e. weather routing) and reduced turn-round time.
viii) Effect of government or other subsidies.
ix) Trades union attributes to "automation".

In some cases advice from technical departments is essential, but technical claims should of course be very carefully scrutinized before inclusion in the financial analysis. At all costs "the nice to have" and the "just another amplifier and meter" attitude should be scotched at birth, since this path leads to inflation of costs and ultimately to a reduction of the return on investment.

Reliability—a major stumbling block in ship automation—is poor and for two reasons; firstly, a lack of appreciation of the environmental conditions aboard ships, particularly in machinery spaces and secondly, because of a failure to define installation procedures (cable terminations, shielding, clipping, earthing etc.) and inadequate supervision during installation.

To a certain extent these shortcomings are being overcome with the publication, by the classification societies and the British Ship Research Association, of environmental test specifications for ship control and instrumentation systems. However, until the system contractor or the yard appreciate that only meticulous specification of every part of the system and equally meticulous inspection of every part of an installation are essential, "automation" systems will be dogged by system unreliability, however good their individual components.—*Budd, E. B., The Motor Ship, February, 1970, Vol. 50, p. 7, Marine Automation Section.*

Unconventional Hull Form

In a paper presented by R. Leopold before the Society of Naval Architects and Marine Engineers, consideration was given to a new form of hull designed to achieve high speeds while satisfying such criteria as low resistance, good seakeeping, seaworthiness, cargo holds having a high storage rate combined with rapid loading and unloading systems, reduced structural weight and lower building cost: a formidable design undertaking it might be thought.

It is pointed out that the displacement hull does not cater for efficient stowage and suffers from high wave-making resistance, which limits the economic speed range. To overcome the limitation of the purely conventional hull in this respect, work has gone forward with catamarans and trimarans, hydrofoils, submersibles and semi-submersibles. The paper puts forward the view that none of these types entirely satisfies all the fundamental requirements and goes on to suggest the consideration of additional variables to the displacement hull. These are aimed at improving the speed/power relationship and cargo storage factors.

The new design put forward by Mr. Leopold consists of three components, namely, a hull for cargo supported, through the medium of connecting hulls, by twin underwater buoyancy hulls. This unusual configuration is named Trisec and it is claimed that the streamlined connecting hulls reduce wave-making resistance, their waterplane area being minimal. The benefit of this is seen at high speeds when the wavemaking resistance becomes the major component of the total resistance with a conventional displacement hull form.

The paper refers to model tests and states that these indicate a substantial saving of power at high speed; this, of course, has to be set against an increase in power over the lower range of speeds. The amplitude of both heaving and pitching motions are shown to be considerably reduced and improved stability is claimed for the new hull form which affords the opportunity to build a cargo hull approximately a box-like shape, with which there would be a minimum of lost stowage space.

Furthermore, it is thought that the uniform shape of the cargo hull will result in some saving in structural weight and that the basic principles of the Trisec design will point the way to economic sea transport at speeds of 40 knots and above. The design appears to ensure reduced wave-induced bending moment. It will be interesting to learn whether further development of the project will fulfil the promise of the model experiments, and avoid wave interference problems. There remains the practical consideration of having two engine-rooms, and twin steering gears; and the question of damage stability would have to be given thought. Nevertheless, the proposals have topical interest at a time when cargo-carrying vessels of 30 knots speed (and tremendous power) are on order. *Shipbuilding International, February, 1970, Vol. 12, p. 46.*

Coaster Converted to Liquid Gas Carrier

The 570 gross ton *Lanrick*, built in 1957 for Geo. Gibson and Co. Ltd., of Leith, underwent a complete conversion recently from dry cargo vessel to liquid gas carrier, suitable for the carriage of propane, butane, butadiene, vinyl chloride, propylene and ammonia at a maximum pressure of 142 lb/in^2. The conversion of this 244 ft long, two-hatch vessel, at Boele's Scheepswerven en Machinefabriek N.V., Bolnes, Holland, involved the installation of two horizontal cylindrical tanks of about 1580 m^3, for which the deck was altered and all woodwork removed from the holds.

The forward tank is about 70 ft long and the after tank, 75 ft, both tanks being 23 ft 7 in in diameter. The loading and discharging installation consists of two deepwell pumps and two horizontal centrifugal booster pumps with a capacity of 160 m^3/h. The booster pumps and compressors have been installed in two pump/compressor rooms and their motors installed in separate compartments. These compartments and the void space around the tanks are mechanically ventilated, the void space being equipped with a gas detecting installation, and a water-spray system is fitted over the tanks and domes. Temperature and pressure controls, and hydraulic quick closing valves are provided for the tanks. The engine-room has been arranged for 12 hour unattended operation.—*The Motor Ship, February, 1970, Vol. 50, p. 543.*

Tuna Seiners for Portugal

A series of three identical tuna seiners for Portugal, each with a "power block" fitted to the jib of the main 10-ton working boom to enable the ship to operate as a purse seiner, has been built by the Seebeck yard of A.G. "Weser" to the order of Congel Cia. de Pesca e Congelacao de Cabo Verde S.A.R.L., Lisbon.

The power block on the jib of the working boom is a hydraulically actuated unit evolved by Marco (Marine Construction and Design Co.) and fitted for hauling in the net up to nearly mast-top level.

This series of vessels, each of about 361 gross tons, has a length b.p. of 34·25 m, a moulded breadth of 9·30 m, a depth to the main deck of 4·40 m and a design draught of 4·20 m. Accommodation for 18 officers and ratings, the main propulsion machinery and the refrigerating installation are arranged forward, leaving the mid-body and stern section clear for eight fish-holds aggregating the working deck. Subsequent freezing of the catch is effected in stages by brinetype freezing starting at -1°C. After 72 hours of brine freezing the catch is eventually dry frozen down to -18°C.

Deck and working machinery include a Seebeck combined hydraulic seiner windlass, the aforementioned Marco power block, an anchor windlass, a cork rope windlass, a choker winch, a topping winch, a cargo winch and guy winches—all of them hydraulically operated—and finally the 17-ton seiner net which is carried aft on a specially designed platform. The net has a length of 860 m and—suspended from buoys—it is trailed by chains and rings at a depth of 108 m. Contrary to usual practice of the vessel's "skiff" towing the seiner net "around" into position, the new Seebeck seiner tows the net around the intended catch, while the polyester 150-hp skiff, of 8 m × 4·60 m, holds the net in position. After closing the seiner net the hydraulically operated power block begins hauling in the net, although it is not intended for hauling aboard the total catch, this being accomplished by "keshers" *via* the 2-ton auxiliary derrick, whereas the 10-ton derrick with power block handles the seiner net and the skiff.

Main propulsion is by a Deutz marine Diesel engine developing 1000 bhp at 380 rev/min, giving the vessel a speed of 11·7 knots. For supplying the ship's main and Sabroe refrigerating machinery, two Struver-Deutz Diesel engines of 258 bhp at 1500 rev/min are installed to drive two generators, each of 169 kW.—*The Motor Ship, February, 1970, Vol. 50, p. 14, World-Wide Fishing Section.*

Det Norske Veritas Rule Amendments

The Scandinavian Technical Committee of Det Norske Veritas met recently to discuss proposed amendments to the Rules covering hull, machinery, security and materials. In the hull technical field the complex problem concerning connexions between continuous frames and girder webs and between continuous frames and stiffeners connected to tops of frames was taken up for assessment together with a Rule proposal regarding the internal loading due to liquids in wide tanks which are permitted to be kept partially filled. Revisions to the rules for windlasses were proposed.

New requirements were suggested for crankshafts in Diesel engines, among other things, crankshafts for Vee-engines. Stipulations for nodular cast iron crankshafts were also included. Proposals were made regarding inspection of lubricating oil systems during surveys.

The security questions group dealt with a proposal regarding additional designations in the Ships Register for ships transporting ballast water mixed with oil. These tankers have special safeguards against explosion.—*Marine Engineer and Naval Architect, January, 1970, Vol. 93, p. 28.*

Service Results of Decca ISIS-300 System

It is now over 15 months since the first Decca ISIS-300 alarm scanning and data logging system was fitted in the container ship *Manchester Challenge*. To analyse service performance Decca has extended the system of monitoring which has proved invaluable on radar equipment over many years. Every fault discovered in inspection, works commissioning, shipboard commissioning and service calls is carefully logged and tabulated. Radar serviceability statistics covering about 25 000 sets are analysed by a computer at the company's Croydon service headquarters, but at present the much lower volume of serviceability data for the ISIS-300 is evaluated by a team of post-design engineers whose task is to identify problems at the earliest possible moment.

The substantial amount of data analysed so far has shown that the majority of problems occur with transducers. This is to be expected, as the transducers are the part of the system in direct physical contact with the ship's machinery. Some early pressure transducer failures indicate that the instruments were over-ranged, and it was found that process pressures were extending far outside the maximum values stated by the machinery suppliers. This applied particularly in fuel and lubricating oil services when pumping cold oils prior to heating through. Decca now allows a factor of at least 100 per cent when selecting pressure transducers for these services. Another difficult transducer area is exhaust gas thermometry, where thermometers have to withstand temperatures up to around 600°C with simultaneous shocks of over 100 g. Service experience shows a meant life of about two years for these thermomemters, although there are infant mortality failures.

The ISIS-300 system scans at 400 channels per second using solid state switching techniques. The system accuracy is generally better than one per cent of range, allowing very fine setting of alarm limits.—*The Motor Ship, February, 1970, Vol. 50, p. 15, Marine Automation Section.*

Diesel Electric Propulsion for German Factory Trawlers

Diesel-electric machinery was chosen for three 2685 gross ton 15½ knot factory trawlers with an endurance of 96 days which were delivered recently by Rickmers Werft, of Bremerhaven, to German owners. Named *Osterreich, München* and *Sonne*, these vessels of 86·5 m length and 14·2 m breadth with a draught of 5·4 m have spacious factory areas and sophisticated unloading equipment.

An a.c. Diesel-electric drive with a common grid for propulsion, trawl winches and factory, using four generators to deliver 650 kW at 380 volts and 50 cycles, is fitted in these ships. This arrangement was found to compare favourably with an originally proposed twin-Diesel engine installation delivering 1900 bhp at 300 rev/min *via* a Vulcan gear-box to a c.p. propeller A dc electric drive would have been more complicated and expensive, and although ac supply made the use of c.p. propellers necessary, those that have been fitted are of the same type as the builder's Bonn Class vessels, so that spates, particularly blades, are interchangeable. Because of possible ice damage this is an important consideration.

When under way without any factory load the four generators, driven by M.a.K. type 8M281 engines, can of course, deliver more current than the two 1 100-kW propeller motors require, but with both factory and trawl winches on full power the generators could become overloaded if too much propeller pitch were allowed. Therefore an overload control automatically reduces the propeller pitch if one of the four generators or two motors is overloaded. Should one of the generators trip out, the pitch will be reduced within seconds so that voltage and grid frequency remain stable.—*The Motor Ship, February, 1970, Vol. 50, p. 10, World-Wide Fishing Section.*

Marine Automation Developments

A complete monitoring system for engine-room machinery has been developed by Saab A/B.

The new system, which operates with a Saab data logger, has already been installed in two 227 000 dwt tankers—*Veni* and *Alva Star*—both built by Gotäverken, and has been chosen as a basic system for series of tankers and OBO ships on order at the same yard. In *Veni* the system monitors 79 points for pressure and temperature measurements, and a further 100 points are equipped with "on/off" sensors; however, there is no limit to the number of points able to be monitored. Both audio and visual warning is given of an alarm and a reading is displayed on an alarm panel. Similar panels are placed on the bridge and in crew cabins.

Standard typewriter print-out is used for the data logging system, with some groups of figures combined with a code letter to ensure easy identification, and as various readings may occur independently, different print-out programmes have been given different priorities. The highest priority has been given to alterations in propeller shaft velocity.

The Saab bearing monitoring system is designed for continuous measurement of main and thrust bearing wear. When the wear in any bearing reaches a preset value, an alarm is given, measurement being based on changes in the magnetic field of differential transformers.

Another development has been in the field of hull strain measurement. This equipment is based on experience in the aircraft industry, and its main purpose is to measure strains in vessel forms, to enable shipyards to evolve new ship designs.—*The Motor Ship, February, 1970, Vol. 50, p. 9, Marine Automation Section.*

Effect of Boundary Lubricants on the Friction of Cast Iron

Friction tests were made in 0–100 per cent additive-white oil blends of constant viscosity, with cast iron specimens, to determine the effect of additive concentration on static and dynamic friction. Friction was nearly the same from 1 per cent to 100 per cent concentration, at 0–50 ft/min sliding speed, for several boundary lubricants. The small effect of additive concentration on friction indicated the additives were nearly fully absorbed at one per cent concentration. The white oil appeared to act only as a diluent in the additive blends. The slopes of the friction against sliding speed curves were smaller for the additive solutions than for neat white oil. The slopes of all the curves became slightly negative at higher sliding speeds because of an increasing degree of fluid film lubrication. Friction data taken with the acid additives was normalized because dynamic friction changed appreciably during the tests, due evidently to chemical wear of the metal specimens.—*Albertson, C., and Wolfram, G., Lubrication Engineering, December, 1969, Vol. 25, pp. 469–474.*

Experimental and Analytical Studies of the Compression Ignition of Fuel-Oxidant Mixtures

The paper describes an approach for predicting the time variation of the state of a non-adiabatic reacting charge undergoing a change in density, such as that in a motored auto-igniting engine or the "end gas" of a spark ignition engine. To describe accurately the rates of chemical reactions involved and to account for the production of intermediate combustion products and their survival, detailed chemical kinetics involving chain reactions are employed.

To test the approach developed, hydrogen gas is employed as a fuel in the closely controlled environment of a specially developed compression apparatus which is closely akin to that of the piston engine, yet more amenable to control and analysis. Subject to the availability of reliable detailed kinetic data for the reactions involved very good agreement between theory and experiment can be achieved. The future implications and utilization of such an approach is discussed.—*Karim, G. A. and Watson, H. C., The Institution of Mechanical Engineers, Proceedings 1968–1969, Vol. 183, Part I, No. 37, pp. 725–738.*

Geometry and Leakage Aspects of Involute Rotors for the Roots Blower

For maximum operating efficiency of Roots type blowers, the leakage of compressed air through clearance must be reduced to a minimum. At the same time it is desirable to keep the design as compact as possible. The following analysis endeavours to show, for involute rotors, the effect of the geometrical design variables, pressure angle, rotor tip radius, and base circle radius, on leakage and compactness.

Firstly limits of permissible values of the geometrical design variables, to allow correct mating between rotors, are established. Within these limits, relative blower compactness and carry-over of compressed air back to the inlet tract is obtained for the ideal blower with no clearance between relative rotating parts. The analysis and results are expressed in dimensionless form independent of blower size, and results are compared with cycloid rotors. *Ritchie, J. B. and Patterson, J., The Institution of Mechanical Engineers, Proceedings 1968–1969, Vol. 183, Part I, No. 36, pp. 707–724.*

An Experimental Investigation of the Influence of Speed and Scale on the Strain-Rate in a Zone of Intense Plastic Deformation

Experiments are described in which an explosive quick-stop device and printed grids (0·002 in^2) were used to measure the deformation (streamlines of flow) in the zone of intense shear in which the removed chip is formed in orthogonal machining. A method is given for calculating the strain-rate from the experimental streamlines and it is shown that both the maximum and mean values of the maximum shear strain-rate in this zone are directly proportional to speed (shear velocity) and inversely proportional to scale (depth of cut).—*Stevenson, M. G. and Oxley, P. L. B., Paper submitted to The Institution of Mechanical Engineers for written discussion; paper No. P.31/70, 1970.*

Methods of Exploiting the Effects of Strain Hardening on the Properties of Steels

This article discusses the results of studies made to determine the influence of the properties of steels of variations in cold-working procedures, notably in connexion with the comparative effects of strain-hardening arising from deformation at both room and elevated temperatures. These results show that, when steels are subjected to plastic deformation at appropriate temperatures, they can develop higher strengths, combined with adequate ductility and toughness, than is generally appreciated. *Nachtman, E. S. and Breyer, N. N. Engineer's Digest, January, 1970, Vol. 31, pp. 49; 51.*

Metacentric Height and Rolling Period

The purpose of this study was to investigate whether it is possible to determine the metacentric height within reasonable limits of accuracy by measuring rolling periods under different working, loading and weather conditions.

Only when stability criteria can be found which take into account the local conditions, as type and class of vessel, specific fishing methods and weather and sea conditions, it will be possible to execute stability calculations for fishing vessels which approximate the real circumstances.—*de Beer, F., International Shipbuilding Progress, February, 1970, Vol. 17, pp. 29–44.*

Interferometric Determination of Elastohydrodynamic Lubrication Contact Pressures

A study has been made of the stress distribution in optical quality glass rolling elements operating under conditions of elastohydrodynamic lubrication, and the pressure distribution in the lubricant film has been inferred from interferometric measurements of the distribution of principal stress sum and principal stress difference on the boundary of the contract region. The absolute retardation method of stress analysis which permits these evaluations has been developed and extended to the measurement of steady-state dynamic stresses, for this purpose. The techniques in use are also amenable to use in the analysis of plasto-elastic elastohydrodynamic lubrication problems.—*Cope, D. L. and Haines, D. J. Paper presented at a meeting of The Institution of Mechanical Engineers, 4th March, 1970; Paper P35/70.*

Delta Technique Extends the Capabilities of Weld Quality Assurance

The Delta Technique is a newly developed multi-search unit ultrasonic inspection method. The test is based on sensing redirected sound energy which originates when a scanning sound beam strikes internal discontinuities. This phenomenon is called the "Delta Effect".

Structures containing various weld configurations have been evaluated with the Delta Technique. Defect character, inspection technique and data recovery are reviewed and compared with other N.D.T. techniques and metallurgical sections. Unique recording techniques have been developed providing flaw depth and size information.—*Cross, B. T., Hannah, K. J., Tooley, W. M. and Birks, A. S. British Journal of Non-Destructive Testing." December, 1969, Vol. II, pp. 62–77.*

Reliability and Maintainability Analysis of Shipboard Systems

The need of an increased emphasis on the reliability and maintainability characteristics of shipboard systems is discussed.

Next, the current reliability and maintainability specification requirements are surveyed and their impact on the marine industry is reviewed. This is followed by a description and evaluation of the various types of reliability and maintainability analyses which may be applied to shipboard systems. Insofar as marine equipments are concerned, the major sources of data, their availability, and utility are also reviewed.—*Harrington, R. L., Coats, J. W. and Farley, F. E. Marine Technology, January, 1970, Vol. 7, pp. 38–54.*

An Analysis of Rigid Sidewall Surface Effect Craft for High-Speed Personnel Transportation

A number of commercial applications have been proposed for rigid sidewall surface effect craft. The transport of crews to offshore operations is an application which is well-suited to the immediate use of moderately sized craft of this type. Because the crews are paid while they are in transit, high speeds are required to minimize the total transportation costs. The characteristics and performance of rigid sidewall surface effect craft suitable for crew transport operations are developed. The major design parameters studied include payload, total power, and machinery type. Performance estimates are made for operations in both calm water and waves. An economic model is developed to simulate crewboat operations.—*Miller, E. R., Marine Technology, January, 1970, Vol. 7, pp. 55–68.*

Evaluating the Seakeeping Performance of Destroyer-Type Ships in the North Atlantic

A technique for the evaluation of the seakeeping performance of destroyer-type ships is presented and applied to four radically different hypothetical ship designs. The procedure involves first the determination of the responses of the four ships to realistic North Atlantic sea spectra, using linear superposition techniques, and assuming the vessels are in short-crested, irregular head seas. Calculations are based upon theoretical response amplitude operators obtained by applying strip theory to determine the response of the vessels to regular waves. The final evaluation is then obtained in the form of long-term probabilities of not exceeding stated numerical indices of performance as functions of ship speed.—*Hamlin, N. A. and Compton, R. H., Marine Technology, January, 1970, Vol. 7, pp. 69–103.*

Non-Destructive Testing as a Metallurgical Aid in Ship Maintenance and Failure Prevention

This paper indicates very briefly some of the areas where N.D.T. has been used as an aid to maintenance and failure prevention in a fleet of fast cargo ships.

It has been written from a metallurgical viewpoint and the author has attempted to show that very simple and relatively inexpensive methods of non-destructive testing can be most useful in the day to day running of a fleet of ships. In this respect it is felt that maximum benefit may be gained from N.D.T. when used in parallel with failure examination.—*Deegan, J. F. British Journal of Non-Destructive Testing, December, 1969, Vol. 11, pp. 86–92.*

Electronic Performance Analyser for Diesel Engines

Extensive testing with numerous engines of different manufacture has indicated that many types of operational defects such as worn pump plungers, cams, crankshaft bearings or broken plunger springs, incorrect pump volume settings, worn or incorrect delivery valves, stuck or intermittently sticking nozzle needles, leaking or coked nozzles and high or low opening pressures can be detected by this electronic equipment operating through the detection and measurement of instantaneous pressures in the injection system lines of Diesel engines. With this method, pressure signals from the Diesel engines first cylinder are used to produce synchronization with crankshaft rotation. Signals are devised from calibrated quartz pressure transducers readily inserted in the lines. No other connexions to the engine are required and hook-up can be made quickly. Traces for each injection line are then displayed on a conventional cathode ray engine analyser, shown in a vertical arrangement to permit immediate comparisons.—*Reeds Marine Equipment News, October, 1969, Vol. 13, p. 18.*

A Method for Calculating the Flow Over Ship Hulls

A computer programme is described which calculates the distribution of Kelvin wavemaking sources over the hull surface satisfying hull boundary conditions exactly and linearized free surface conditions. This gives fair estimates of wavemaking (with allowance made for frictional reductions of stern waves) and good predictions of flow over the hull.—*Gadd, G. E., Paper submitted to the Royal Institution of Naval Architects for written discussion. Paper No. W1(1970).*

Computer-Aided Structural Design of Bulk Carriers

The paper is primarily concerned with the automatic structural location and determination of the longitudinal strength members of bulk carriers.

Some aspects which are discussed include the use of a structural mathematical model in determining the scantlings, to the requirements of Lloyd's Register of Shipping, for any ship size and internal structural arrangement, and also the use of stiffener selection sub-routines for rolled steel shipbuilding sections. The establishment of a deck structure to satisfy a particular standard of longitudinal strength is included in the design process and this too is discussed.

By using the model, systematic parametric studies have been made for bulk carriers ranging in size from 20 000 tons to 80 000 dwt in order to investigate the longitudinal steelweight behaviour. These results are given in the paper.—*Aldwinckle, D. S., Paper presented at a meeting of the North-East Coast Institution of Engineers and Shipbuilders, March, 9, 1970.*

Analytical Prediction of Thrust Deduction for Submersibles and Surface Ships

An analytical method which is based on the Lagally steady-motion theorem is presented for the numerical calculation of thrust deduction for body and propeller systems. It is assumed that the influence of a propeller on a hull is mainly potential in origin, whereas the influence of the hull on the propeller is essentially viscous in origin. In the method, a lifting-line representation is used for the propeller, the potential flow due to the hull is obtained from the Douglas-Neumann programme, and the real total wake is determined experimentally.—*Beveridge, J. L., Journal of Ship Research, December, 1969, Vol. 13, pp. 258–271.*

Non-destructive Testing for Structural Stability

The principles of a procedure have been developed for predicting the buckling load of a structure by applying loads considerably below the buckling value and probing the structure to determine the consequent loss of rigidity induced by the applied load. The basis of the procedure is the vanishing of the structural rigidity at instability, which implies that the probing force should become zero at the critical load. Therefore, it should be possible to predict the magnitude of the instability load by utilizing an appropriate extrapolation procedure to determine the load level at which the probing force vanishes.—*Becker, H., Journal of Ship Research, December, 1969, Vol. 13, pp. 272–275.*

On-Line Analysis of Wet Combustion Gases by Gas Chromatography

A technique is presented for the on-line analysis by gas chromatography of a single sample of wet combustion gas containing the following components: CO_2, CO, H_2, H_2O, O_2, N_2, CH_4, C_2H_4, C_2H_6. This analysis is not usually attempted with a wet gas, or with a single sample. A hot-wire detector is used to detect components, which are separated on a dual column system. The columns used are 4-metre Poropak 'Q' and 2-metre Molecular Sieve 5A at a helium carrier gas flow rate of 0·688 cm^3/s. A switching valve is incorporated to divert the sample between the columns. The technique has been used successfully for the analysis of combustion gases withdrawn isokinetically from a residual fuel oil-fired combustion system. The paper contains no quantitative data.—*Archer, J. S., Journal of the Institute of Fuel, February, 1970, Vol. 43, pp. 56–58.*

Orbitest for Round Tubes

The basic principles of eddy current testing are reviewed, and inspection techniques applicable to seamless tubular products are discussed. The Orbitest uses four probe coils which perform the dual functions of inducing eddy currents and detecting defects. Each probe operates independently. The plurality of probes provides increased inspection rates. The four probes are mounted on a hollow cylinder which encircles the tube. The cylinder is rotated as the tube is conveyed longitudinally through it so that the probes orbit the tube and generate a helical scan on the outside surface. Readout is by a chart recorder and a paint marking system which marks the locations of defects on the tube.—*Judd, T. W., Materials Evaluation, January, 1970, Vol. 28, pp. 8–12.*

Self-Regulating Steam Generator: a Progress Report

The self-regulating steam generator is a device designed to help achieve single-lever controllability of a marine steam plant. This paper presents an abbreviated history of the S.R.S.G. development, defines the scope of control provided by the new system, and describes at some length the purpose, procedures and results of actual boiler testing during the period from initial boiler light-off to completion of the preliminary test operation.—*Seelinger, J. H. and Nagengast, J. E., Marine Technology, January, 1970, Vol. 7, pp. 10–20.*

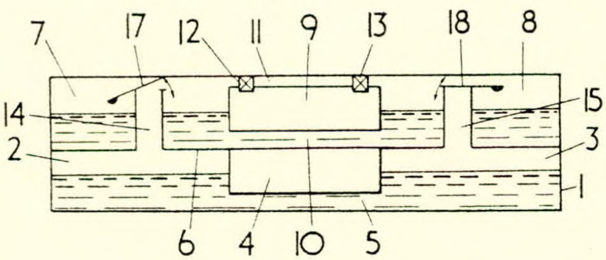
Patent Specifications

Stabilizers

This invention relates to passive stabilizers using a two-tank arrangement.

Fig. 1 shows diagrammatically an athwartship section through the hull of a vessel. The port and starboard bilges of the vessel are respectively provided with two tanks (2, 3), partially filled with liquid, in this case water, and communicating with one another by means of a channel (5) passing beneath a central obstruction (4). A deck head (6) above the two tanks (2, 3) supports a second two-tank arrangement comprising a pair of tanks (7, 8) which are separated from one another by a central obstruction (9). The two tanks (7, 8) are also partially filled with liquid, in this case also water, and communicate with one another towards their lower ends by way of a connecting channel (10) passing beneath the central obstruction (9).

FIG. I.



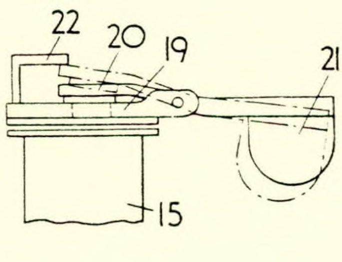


FIG. 2.

The air spaces above the water in the two tanks (2, 3) open upwardly through two upright trunks (14, 15) into air spaces formed above the water level in the two tanks (7, 8). A valve, shown in more detail in Fig. 2, and referenced (17, 18) in Fig. 1, is normally open and allows air flow through the upright trunks (14, 15).

In Fig. 2 it will be seen that each of the trunk valves comprises an apertured valve closure member (19) pivoted to a side flange (not shown) on the trunking, and which spans across the top of the trunking (15). A pilot valve closure member (20) actuated by a counterpoise float (21) is pivotally mounted on the pivotal axis of the closure member (19) so that it can open and close the aperture in it. The movement of the pilot valve closure member is limited by an angle stop (22) fixed to the valve closure member (19).

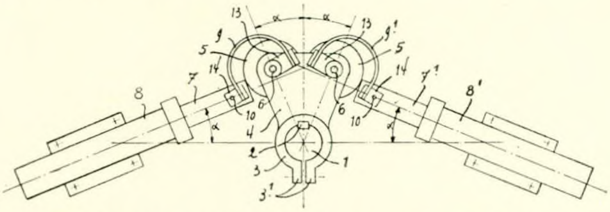
The air spaces containing the valves (17, 18) communicate with one another through an air duct (11) disposed above the central obstruction (9) and provided with valves (12, 13) at opposite ends to control the flow of air between the two tanks (7, 8). Duct (11) is common to both tank systems.

The stabilizer operates in the following manner. Under normal conditions, the trunk valves (17, 18) will both be normally open (as shown in the left-hand half of Fig. 1) and as the ship rolls, the phase of the water displacement is controlled by the valves (12, 13). The settings of the valves (12, 13) are such that the rolling of the ship is dampened by the controlled movement of the water between the two tanks of both two-tank arrangements.—*British Patent No. 1 169 631 issued to Muirhead and Co. Ltd. Complete specification published November 5th 1969.*

Hydraulic Steering Gear

This invention relates to an improvement of British Patent No. 907 631. The drawing, as in the parent patent, shows the rudder stock (1) of a rudder to which a rocker is fixed, as for example, by a key (2). This rocker consists of a sleeve (3) with two lugs (3') connected by a locking pin. A single arm (4) of the rocker is substantially triangular in general shape and carries at each of two corners a roller (5). These rollers are engaged by rams (7, 7') moving in cylinders (8, 8').

If hydraulic fluid enters one of the cylinders, the corresponding ram acts on its corresponding roller (5), rotating the rocker (3, 4) and therefore the shaft (1). At the same time the peripheral surface of the roller (5) rolls on the flat end surface of the ram.



Permanent contact between each ram and its rollers is ensured by a resilient element (9, 9') connected at one end to a yoke (13) pivoted on the rocker arm (4) and at the other end to a member (14) fixed by a pivot (10) to the respective ram.

The angular distance between the centres of either of the two rollers, with respect to the centre of the shaft is α.

In the drawing the rams are shown in mid-stroke, and as can be seen the longitudinal axes of the cylinders are each perpendicular to the respective radial line connecting the centre of shaft (1) to the respective roller centre. In this position the longitudinal axes of the cylinders are each so positioned as to form, together with the line shown on the drawing passing through the centre of the main shaft and perpendicular to the plane of symmetry of the rocker, an angle α equal to half the angle 2α formed between the lines shown on the drawing connecting the centres of the rollers and the centre of the main shaft.—*British Patent No. 1 169 590 (patent of Addition to No. 907 631) issued to A. Brusselle. Complete specification published 5th November 1969.*

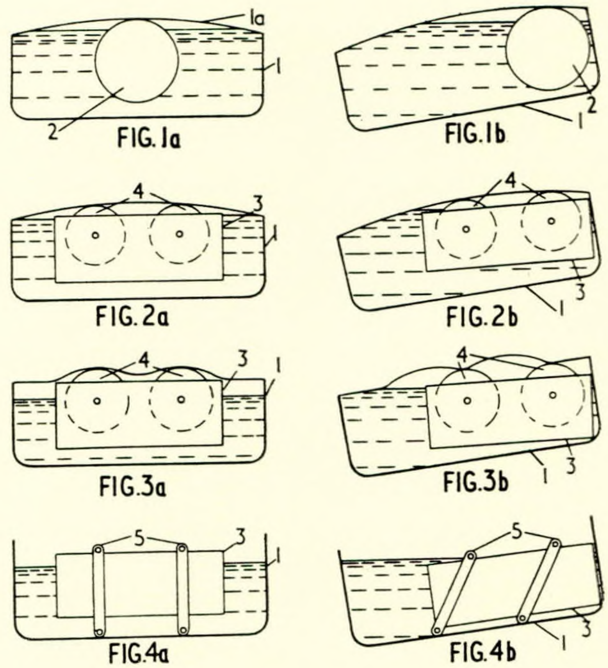
Tank Systems for Stabilizing Vessels

This invention relates to a tank system for stabilizing a vessel. In Figs 1a and 1b a tank (1) of parallelepiped shape is substantially full of water and has a free surface. A buoyant member in the form of a hollow sphere (2) is located in the tank and presses upwardly against the arched roof of the tank which has a pronounced curvature. When the vessel is on an even keel, the sphere (2) is in the centre as shown in Fig. 1a. When the vessel rolls in one direction, as shown in Fig. 1b, the sphere (2) moves to one side as shown, and, in so doing, displaces some of the stabilizing liquid in the opposite direction. In this way the displaced liquid applies a load to the side of the craft that is about to ascend. This movement of the liquid in a known tuned periodic manner causes a stabilizing moment to be exerted on the vessel.

In the second tank system shown in Figs 2a and 2b, the buoyant member is in the form of a parallepiped buoyant body (3) provided with rollers (4) which protrude beyond the upper portion of the body (3) and run along the arched roof of the tank which thus provides a path of pronounced curvature.

In the system shown in Figs 3a and 3b, the roof of the tank is provided with two outwardly curved surfaces against which the rollers (5) bear. The position of the member (3) is determined in part by the tilt of the vessel and in part by the pronounced curvature of the outwardly curved surfaces in the tank roof.

In the embodiment shown in Figs 4a and 4b, the path of pronounced curvature along which member (3) moves, is determined by a pair of parallel spaced links (5) which are pivoted at their lower ends to the floor of the tank and at their upper ends to the upper surface of the member (3) as shown at (5).



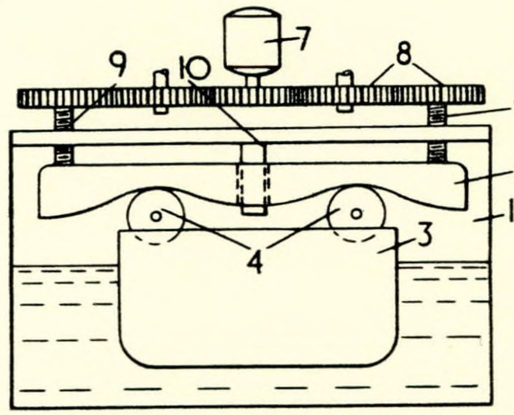


Fig. 6

In Fig. 6 the buoyant member (3) is contained within the tank (1) and is provided with rollers (4) which run along the track (6) providing a path of pronounced curvature for guiding movement of the buoyant member from side to side in the tank (1). A motor (7) drives a set of five meshing gear wheels of which the outer two have threaded stems (9) passing downwardly through the roof of the tank and threadably engaging opposite ends of the track (6). A stop pin (10) is provided to engage in a recess in the upper surface of member (3) in any other predetermined position by suitable means not shown.

The system of Fig. 6 has the advantage that the motor (7) can be run to vary the height of the track (6) within the tank (1). This in turn controls the depth of immersion of the buoyant member (3) and thus the vertical height of the passage formed between its undersurface and the floor of the tank. In this way the tuning frequency of a given installation may be varied.—*British Patent No. 1 167 547 issued to Muirhead Ltd. Complete specification published October 15th 1969.*