TECHNICAL ABSTRACTS

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PROPELLERS AND PROPULSION

Researches on the Prevention of Cavitation and Erosion of Ship Propellers (Japanese). *Shipbuilding Research Association of Japan, Report No.* 13, Jan., 1957 (74 pp.).

This report describes cavitation tests carried out for both model and actual propellers. An analysis is also given of actual propeller-blade failures over a period of six months. The sea tests were carried out with a 9-metre (29·5-ft) research boat belonging to the Fisheries Agency, in the course of which the generation of cavitation on the propeller blades was studied. By a combination of analysis and observation, information was obtained concerning the inception and disappearance of cavitation when the propeller blades pass through the uneven wake distribution. The results were embodied in a chart for cavitation prevention in the design stage.

Investigations were also carried out on materials resistant to erosion, corrosion, and dezincification. It was found that the resistance to corrosion of a high-strength brass is improved considerably by the addition of 1·0–3·0 per cent aluminium.

There is an English summary.

MATERIALS : STRENGTH, TESTING AND USE

Titanium—An Answer to Corrosion Problems. STOUGH, D. W. and PEOPLES, R. S. *Ship and Boat Builder*, **10** (1957), p. 164 (May) (3 pp.).

At the present time there is very little titanium metal in actual marine service, primarily because of its high cost. Titanium is a strong, light metal available commercially. The unalloyed metal can be obtained with a yield strength of 50,000 to 80,000 lb/sq in, while alloys may run as high as 150,000 lb/sq in. In addition to good strength values, titanium offers good ductility with tensile elongation varying, depending on the alloy, from about 10 to 20 per cent in 2 in. Titanium is useful in temperatures up to about 800 degrees F. and developments to raise this limit are in prospect. At higher tenperatures, strength falls off rapidly, and oxidation and instability become problems. Unalloyed titanium can be welded satisfactorily with proper shielding from contamination. Although data are limited, titanium welds do not appear to be susceptible to localized corrosion as are stainless steel welds in some cases. Tests carried out in marine environments have shown that titanium possesses excellent corrosion resistance, better than that of aluminium or nickel-base alloys, to sea water. Experiments showed that titanium was nearly as resistant to cavitation as the special cast-steel alloy (16 Cr–6 Ni) used in marine service to avoid cavitation damage. In addition to excellent resistance to sea water, titanium is quite resistant to gaseous marine environments. Tests showed that the critical velocity beyond which protective films are swept away is greater than 25 ft/sec. for titanium. Like stainless steel, titanium owes its corrosion resistance to a surface passivation process rather than any inherent property. It appears, however, that the passivation process on titanium is more effective than on the stainless steel alloys.

The U.S. Navy is employing titanium for a number of services including sea-water pumps, Snorkel tubes, wet exhaust silencers, and fresh-water extraction equipment. It seems safe to predict a significant and increasing use of the metal for marine purposes.

GAS TURBINES

Fuel Systems for Marine Gas Turbines. FINNIGAN, J. *Allen Engineering Review*, No. 37 (1957), p. 23 (Mar.).

W. H. Allen, Sons and Co. Ltd. have developed gas turbines suitable for driving 350-kW generators or alternators on board ship. The fuel supply and control system for an emergency or stand-by set will differ from that for a base-load set. In the former, the fuel system must operate in a fully-automatic manner, so that on pressing a button the engine will start, accelerate to no-load speed, and accept load within one minute. For a base-load set, a semi-automatic system is required ; the machine is accelerated to no-load speed under control of the operator and must then accept load automatically. The Author describes in detail, with the aid of diagrams and characteristic curves, the pumps, valves, burners, and igniters which have been used with both types of set. Information is also provided concerning test-rig and operational performance. The main fuel controller under steady-running conditions is an automatic by-pass valve, hydraulically controlled by the governor. Limiting valves are provided to restrict the temporary increase or decrease in flow rate which occurs on load-changing. The use of high pressures and of fuels with poor lubricating properties has made gear pumps unsuitable. The fuel pump hitherto used is of the positive-displacement, variable-stroke, multi-plunger type. Spill burners were tried, but proved unsatisfactory and have been replaced by duplex burners. An emergency shut-off valve is placed in series with the burner, and allows fuel to pass as long as governor input pressure is maintained at 60 lb/sq in. The Allen base-load set burns gas-oil, which is easily ignited by a surface-discharge plug ; with marine Diesel fuel, as used in the emergency set, a pilot spray is of great value.

Free-Piston Engines for Large Passenger Liners. JACKSON, S. B. *Shipbuilding and Shipping Record*, **89** (1957), p. 711 (30th May) (2 pp.).

In connection with the decision of the P. and O. Company to build a 45,000-ton passenger liner propelled by turbo-electric machinery developing some 85,000 s.h.p. the Author examines the relative cost and other principal characteristics of a turbo-electric plant such as might be used on the new ship with those of a plant of equivalent power but consisting of free-piston generators and gas turbines. For the steam plant he assumes four boilers each with an output of 150,000 lb/hr (max.), supplying two 26,400-kW turbo-alternators. The steam conditions at boiler outlet are assumed to be 925 lb/sq in and 950 degrees F.

In the alternative plant, the gas turbines would work with gas at 825 degrees F. and might with advantage be geared to an epicyclic reversing gearbox of, say, the Stoeckicht type ; the necessity for reversing stages would thereby be eliminated, and full power would be available for reversing.

The results of the estimates are summarized as follows :—

	Turbo-electric	*Free-piston*	*Saving*
Thermal efficiency, per cent ..	28·8	38·4	—
Fuel consumption, lb/s.h.p. hr. ..	0·475	0·359	—
Fuel consumption for 12,000 miles, tons	6,500	4,900	1,600
Machinery weight, tons	8,000	3,000	5,000
Machinery space (volume), per cent ..	100	about 70	about 30·
Machinery cost	£3,275,000	£1,900,000	£1,375,000

The above figures are for a steam plant without re-heat ; if re-heat up to, say, 925–950 degrees F. is used, the fuel consumption might be reduced to 0·455 lb/s.h.p. hr.

The table applies to the main machinery only, but in the case of the free-piston engines the power developed by the main machinery would also cover all auxiliary requirements, simply by using the large amount of heat available in the gas-turbine exhaust to generate steam for auxiliary turbines, space heating, etc.

Auxiliary power would therefore be provided at no extra fuel cost. A further advantage of the free-piston engines is the high velocity of exhaust gas which would permit its discharge through stern pipes, and the absence of soot and grit in the exhaust. This would eliminate the problem of deck fouling by smoke.

British Marine Gas Turbine with Free-Piston Gasifiers. *Gas and Oil Power*, **52** (1957), p. 113 (May) (1 p.).

The 5,444-ton British India Steam Navigation Company's vessel *Ormara*-built in 1947, and propelled by a steam reciprocating engine and an exhaust, steam turbine, is to be re-engined by Alexander Stephen and Sons Ltd., Linthouse, with a geared gas turbine and free-piston gasifier. The 4,000-s.h.p. reversing gas turbine, which is to be built by the British Thomson-Houston Company, comprises separate ahead and astern turbines, and the reduction gearbox. The ahead turbine is a six-stage reaction-type machine and is flexibly coupled at the after end to a 6,800/110 r.p.m. double-reduction gearbox There will be four GS.34 free-piston gasifiers, manufactured by Alexander Stephen and Sons Ltd., under licence from Alan Muntz and Co., Ltd.

The gas turbines for the *Ormara* will be first made by B.T.H. for operation with free-piston gasifiers. The ahead turbine, being a uni-directional and separate unit, is offered for installations using a controllable-pitch propeller for reversing.

NUCLEAR POWER

Nuclear Propulsion of Merchant Ships. *Motor Ship*, **38** (1957), p. 18 (Apr.) (1 p.).

A technical and economic study of nuclear-powered oil tankers has been carried out for the Norwegian shipping industry. Tankers between 20,000 and 45,000-tons d.w. with block coefficients ranging from 0·65 to 0·80, and speeds from 14 to 24 knots, were investigated. The study covered only thermal heterogeneous boiling (heavy or light) water-moderated and cooled reactors. Voyages of 9,000, 13,000, and 17,000 miles were considered.

The economic comparison led to the conclusion that nuclear-powered tankers could operate with a slight economic advantage when compared with conventional tankers.

After investigating many possible power cycles, the boiling-water reactor with intermediate heat exchangers was selected for detailed investigation, in preference to one in which steam is supplied direct from reactor to turbine. The possibility of superheating the steam by oil-fired superheaters (as originally adopted for the submarine *Sea Wolf*) was discarded.

Marine power plant may undergo sudden and large changes in power demand, the range required being as high as 4 to 1. To overcome the problem of removing heat from the reactor during power surges, a by-pass arrangement has been worked out which can be incorporated in the manœuvring valve, permitting the main condenser to be used as a heat dump.

The total weight of the entire 20,000-b.h.p. unit, including reactor, heat exchangers, pumps, valves, piping, and shielding, is estimated at 1,000 tons. Conventional boilers of the same capacity would weigh about 275 tons and the corresponding bunker capacity would amount to 3,000–4,000 tons. Assuming a fuel burn-up of 6,000 megawatt days per ton, a new fuel charge would be required after about 47 months of operation.

Application of Nuclear Energy to the Propulsion of Merchant Ships (French). Cahen, G. and Ricard, J. P. *Ass. Tech. Marit., paper read* June, 1957 (30 pp.).

The Authors explain the principles on which nuclear reactors operate, and show how the many possible types may be classified systematically. This is followed by a discussion of the poisoning problem, and of the other factors which limit the life of fuel elements and influence the maximum economic utilization of the fissile material. Continuous changing and recycling of fuel elements is scarcely possible on board ship ; it will be necessary to renew the whole fuel charge at intervals of one or two years, preferably during the usual overhaul period. A natural uranium reactor, using heavy water under pressure as both moderator and coolant, could probably be applied to ship propulsion. Other practical systems require enriched fuel. The price of fuel rises with the degree of enrichment, but the size of the reactor is reduced and it is possible to use more resistant sheathing materials, e.g. stainless steel. Also, the fuel is more efficiently utilized, since it can be economically recycled a greater number of times. Possible alternatives to the well-known pressurized-water reactor are considered. One very promising system is the enriched-uranium reactor moderated with beryllium oxide and cooled by carbon dioxide, which also serves as the working fluid for a closed-cycle turbine.

The operating conditions of a marine reactor are more arduous than those for a land installation. It must have a high power output per unit weight and a low specific volume. From this viewpoint, the competitive prospects of nuclear power increase with the horse-power and range required. The reactor must be safe and reliable during normal operation either in port or at sea, and must not impair the health of the crew or pollute the sea in the event of damage or foundering. The temperature coefficient of reactivity must be negative, and the reactivity must fall in the event of a breakdown in the coolant circuit.

The chain reaction can be rapidly stopped by injecting boron salts into this circuit, but this has no effect on residual radioactivity. The power output of the reactor should preferably be variable over a wide range, and the reserve of reactivity should be sufficient to ensure immediate starting. Specialized equipment and personnel must be available for maintenance. Lastly, the plant must be competitive with other types. The principal expenses involved are the price of the initial fuel charge ; the price of fresh charges or re-processing ; the paying off of the invested capital ; and special maintenance expenses. It appears that a moderate amount of enrichment is necessary to obtain a reasonable cost per h.p. hr. The cost of nuclear machinery per installed horse-power will probably be about five times that of conventional plant. The capital invested in the construction of the ship is thereby doubled. If it is assumed that the fuel costs of a conventional steam-turbine ship during a life of 25 years are equal to the initial capital investment, the nuclear ship will begin to be economic when the cost per h.p. hr. is about a third of that for the conventional ship. This will probably be attainable, because as nuclear ships pass beyond the experimental stage fuel and material costs will tend to decrease. Some recent projects are briefly described.

There is a bibliography.

LUBRICANTS AND LUBRICATION

Diesel-Engine Lubricants : Their Selection and Utilization with Particular Reference to Oil Alkalinity. DYSON, A., RICHARDS, L. J. and WILLIAMS, K. R. *Institution of Mechanical Engineers, paper read* 17th May, 1957.

The main functions of heavy-duty lubricating-oil additives are to reduce engine-fouling, bearing corrosion, and wear of liners and piston rings. Alkalinity is desirable for the reduction of wear and is one of the major requirements for the avoidance of piston fouling when conventional organo-metallic additives are used. In a well-balanced oil, sufficient dispersive power and oxidation stability may be incorporated to ensure adequate piston cleanliness and freedom from bearing corrosion, provided that the alkalinity level is satisfactory. The alkalinity falls during service, and for satisfactory performance with certain types of additive in common use it must be kept above a minimum value. For these additives, equations are given which enable the variation of alkalinity level with time under given circumstances to be predicted approximately. The most satisfactory arrangement is to use an oil containing sufficient alkalinity, so that the concentration never falls below the critical value. The oil-change period is then determined by other considerations, for example, contamination with abrasives. If an oil of lower alkalinity is used, the equations provide an approximate estimate of the oil-change period, determined solely from the aspect of additive effectiveness. The application of these results to engines with separate cylinder lubrication is discussed. Thus oils, and, where appropriate, oil-change periods, may be selected on a rational basis instead of by trial and error.

Reference are given.