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PRINCIPAL CONTENTS

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FRONT COVER ILLUSTRATION

A Ferranti action data automatic (ADA) system control desk on a County class missile destroyer.

(Picture by courtesy of Ferranti Limited)

Artist's impression of HMS 'Amazon'

HMS Amazon launched

The first 21 frigate

On Monday, April 26, HRH Princess Anne launched her first Royal Navy ship when she named HMS Amazon—first of the new Type 21 class frigates —at the Woolston shipyard of Messrs Vosper Thornycroft Ltd.

The ship, which was designed by Vosper Thornycroft in collaboration with Yarrow, has a displacement of some 2,500 tons, a length of 384ft and a beam of 41¾ft. She is fitted with sophisticated Ferranti weapon control system, and her Rolls-Royce gas turbines will give her a speed of 34 knots. Provision is included for carrying the new naval helicopter, the WG13, and the guided missile Seawolf.

She will be capable of contributing effectively to the defence of a convoy, or other force, against attack by surface ships or submarines, and fully able to defend herself against aircraft, missiles or fast patrol craft. She will match comparable contemporary foreign warships in fighting power and performance, and be able to maintain all-weather patrol in any part of the world.

This is the first occasion in recent years when a major fighting ship for the Royal Navy has been designed commercially.

The new ship's armament consists of one Vickers 4·5in Mark 8 automatic gun and mounting, quadruple launcher for Short Seacat anti-aircraft missiles, Westland WG13 helicopter armed with air-to-surface guided missiles and torpedoes, two 20mm Oerlikon guns, two sets of triple torpedo tubes, and two 2in rocket flare launchers. There is also of course an outfit of small arms. Later ships of the class will carry the new Seawolf missile system with its associated radar and trackers.

Above-water surveillance will be by Type 992Q long-range air-warning radar, as well as Type 978 navigational radar with a true-motion display on the bridge. Anti-submarine search will be by sonars of the latest British design for surface warships.

Action information and weapon control functions are carried out by equipment specially developed for the Type 21 by the Digital Systems Department of Ferranti Ltd. This consists of two interconnected systems, each incorporating a Ferranti FM1600B micro-circuit digital computer. Together these systems, which are housed in the operations room, provide for the correlation and evaluation of tactical information, for target indication and for the control of all weapons, including the helicopter. There are six separate but switchable horizontal displays for the Commanding Officer and operations room staff.

The first system, which carries out the action information and anti-submarine warfare functions, is essentially similar to CAAIS (computer-assisted action information system), and, like CAAIS, uses Decca display consoles. The Type 21 system does, however, provide some functions over and above those of the RN's other CAAIS installations, notably the control of the ship-launched anti-submarine homing torpedoes.

The second system provides fire control for the 4.5in. gun and Seacat missile. Selenia Orion radars track the target and the system provides control for anti-aricraft, surface or shore bombardment engagements, aiming being by radar, by television, or visual sight.

Both systems incorporate many features designed to simplify procedures and reduce reaction times, so imposing smaller manning requirements than any comparable system so far used by the RN Ferranti's Digital Systems Department have acted as weapon systems engineers for the Type 21, specifying operational systems, including radars and displays. They will continue to co-ordinate the installation and commissioning of the systems, and their presentation for the official acceptance trials.

The ship also carries modern IFF and electronic warfare equipment. The communications equipment includes full ship-to-shore and ship-to-air radio systems, with teleprinter and teletype facilities. Some systems are provided with remote control from the bridge and operations room. Visual signalling equipment is of new design. The ship is degaussed and the design embodies noise-reduction measures.

The Type 21's hull design has undergone extensive hydrodynamic development to provide the best combination of speed and sea-keeping ability. Computer analysis at the Admiralty Experiment Works, Haslar, of the hull form's response to both regular and irregular seas has made possible comparison with the behaviour of the Leander class frigates. The results indicate some improvement, especially at the higher Beaufort scale numbers, even over the sea-keeping qualities, acknowledged as excellent, of the older ships.

Navigational aids

The superstructure houses an enclosed bridge, with open wings at the same level, giving the fullest possible all-round view from the central pelorus, which contains a gyro-compass repeater. The bridge will house the steering control and engine telegraphs; automatic steering is to be fitted. Navigational equipment includes master and secondary gyro compasses, magnetic compass, electromagnetic log, echo sounder, automatic radio direction finder, Decca Navigator and Loran. The helicopter hangar forms the after part of the superstructure.

The operations room, incorporating the sonar control room, is immediately below the bridge, with the main communications office and electronic warfare office adjoining.

Accommodation

Accommodation is provided for a ship's company of 192, but the normal complement will not exceed 170, the difference providing a margin to accommodate training classes or other additional parties. In accordance with the latest standards the ship is fully air-conditioned and provided with heating for the coldest conditions. The whole ship's company sleeps in bunks in accommodation to a higher standard than in any previous surface warship. The victualling complex, including canteen, galley, scullery, separate dining halls for senior and junior ratings, and all necessary stores, with cool room, deep freeze and cold store, and controlled temperature store for vegetables, are grouped together and served by a vertical hoist. Special provision is also made for cool stowage of beer.

Other accommodation spaces provide for training, offices, laundry, sick-bay and recreational facilities including television, library, sound reproduction equipment, and cinema.

Main and auxiliary machinery

The Type 21 will be one of the first ships for the Royal Navy to be designed from the outset for all gas-turbine machinery in a twin-screw COGOG arrangement. The main engines are two Rolls-Royce Olympus TM3 gas turbines giving the ship a top speed of about 34 knots. The Rolls-Royce Tyne RB 209 engines for cruising enable the ship to cruise at 18 knots for 4,500 nautical miles. The power plants drive Stone Manganese Marine controllable pitch propellers through SSS clutches and David Brown reduction gearboxes.

To provide the electrical power requirements of the Type 21 and her advanced weapon systems, four diesel generator sets are installed. Power is distributed from the main switchboard to five load centres, control local areas throughout the ship. Emergency arrangements make it possible for the propulsion machinery to continue operating for a limited period in the event of a total failure in the electrical supply.

The machinery arrangement has been designed so that main and auxiliary machinery units can be removed and replaced, complete or in sub-assemblies, with a minimum of dislocation. The compact modular design possible with gas turbine propulsion machinery lends itself to this, and is one of the major advantages of the gas turbine for warship propulsion.

Main and auxiliary machinery, electrical generators and power distribution, are all remotely controlled from a Ship Control Centre, which also houses a secondary steering position and the damage control headquarters.

The ship is designed to carry food stores for 60 days and naval stores for 45 days, though monthly storing would be regarded as usual. Departmental workshops and maintenance spaces have been provided for in the design. Spares for equipment, machinery and weapons, sufficient for about four months are carried. Special consideration in the design has been given to the needs or replenishment of fuel, water and dry stores, at sea and in harbour, with particular attention to routes between reception points and store rooms and magazines.

The Amazon will be the ninth ship of the Royal Navy to have her name. The first was a 6th rate of 471 tons captured from the French in 1745, the last a destroyer built by Thornycrofts in 1926 that served in the Atlantic and on Malta convoys in World War 2.

Major new facilities for Vosper Thornycroft

Vosper Thornycroft are to spend over £1 million on further modernisation of their Woolston, Southampton, shipbuilding yard. The main items in the new scheme are two new covered building berths for ships of about 450ft long and an extended fitting out quay, so that berths alongside for two large frigates, one ahead of the other, can be provided.

The new building providing the covered berths will occupy the area between the present steel stockyard and the River Itchen. One of two existing building berths alongside the prefabrication shop will remain in the open, at least for the present.

Extension northwards of the fitting out quay has been made possible by Vosper Thornycroft acquiring the sites between the existing shipyard and the floating bridge terminal. This area will be re-developed to give access from the yard, and new cranage. The present buildings on the site will be used for storage and offices.

Improved access to ships fitting out alongside the extension of the fitting-out quay, together with better fitting-out and storage facilities will contribute to increased efficiency.

Productivity will be raised by using covered building berths, because better artificial lighting can be provided for work outside daylight hours, and work will not be disrupted by the weather. Covered building berths also mean better working conditions for shipyard employees, who will have an environment more like that of a factory. As well as making life pleasanter these conditions will help the company to attract the additional labour they will need to carry out their future heavy work load.

The present phase of development is due for completion in 1972, subject to final planning permission.

An artist's impression of the river frontage of the Woolston, Southampton, shipyard of Vosper Thornycroft. The tallest shed, on the right, houses the new building berths. The extension to the fitting-out quay is at the left of the picture, with the Woolston terminal of the Floating Bridge on the extreme left

Tuned tank vibration damper

NPL design tested at sea in H.M. Ships

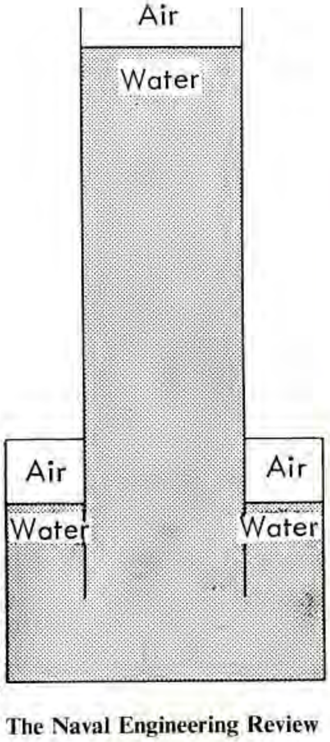
Low-frequency hull vibration, in which the central part of a ship oscillates vertically with respect to the ends, can cause high and repeated additional stresses, quite apart from being a source of discomfort to the ship's company. Such vibrations can be damped-out by counter-oscillations induced in a quantity of water within a tank integral with the structure, as has been shown by the successful full-size tests sponsored by the National Research Development Corporation on board the destroyer H.M.S. *Scorpion*.

Developed by the National Physical Ship Division, the damper and the test equipment were installed in *Scorpion* by Rosyth Dockyard. The N.P.L. Ship Division, the British Ship Research Association, Lloyd's Register, N.R.D.C., and the Naval Construction Research Establishment, Rosyth, where the trials were carried out, jointly provided the trials team and the instrumentation. Subsequently the operation of the damper was demonstrated to leading shipowners and shipbuilders. Designs for specific ships have been carried out by the N.P.L. Ship Division, and the first seagoing installation may be fitted into a large merchant ship shortly.

Wave-excited low frequency vibration has been known for many years, but only with the emergence of very large all-welded ships has it attracted attention as a potentially serious problem. These vibrations arise because ships have a low natural frequency of vibration, between 30 and 60 cycles per minute, which corresponds to and is excited by the ship's passage through waves. These can reach an amplitude which gives rise to appreciable stresses, which moreover, are repeated every second so so, thereby progressing fatigue of the steel structure.

It would be quite uneconomic to construct a ship's hull with a frequency high enough to be immune from such vibrations, but these can be reduced by change of course so that the waves are not encountred at the exciting frequency, by a reduction in speed or by ballasting, each of which can be costly. An alternative is clearly desirable. Instead of changing the ship's frequency its damping can be increased.

Years ago experiments were undertaken with a sprung mass damper fitted at the after end of the Italian motorship *Giulia*. The N.R.D.C. work uses a similar principle but employs water as the mass and air as the spring, thus obviating mechanical complication and wear, at remarkably little cost. Initial calculations indicated the feasibility of the idea and the recently concluded full-scale trials have confirmed the prediction and provided data for future design. The damper tank in H.M.S. *Scorpion* contains about 10 metric tons of water, of which 3·5 tons are active, i.e. supported by the compressed-air cushion. In later designs the active mass will have a higher proportion of the total. During the test the ship was moored and excited at the appropriate frequencies by a vibration generating machine consisting of a driven shaft with out-of-balance masses. Measurements were made of the vibration amplitudes with and without the damper in action. H.M.S. *Scorpion* had a displacement of only 2,500 tons but the results confirmed the validity of the design procedure for more general application. Further experiments and calculations have indicated that vibration amplitudes for a constant input may be reduced by a factor of as much as six by using an active mass of approximately one thousandth of the displacement, depending upon the characteristics of the ship.



Air trapped in the lower tank acts as a pneumatic spring. The system can be tuned to give the optimum damping effect

*A look at gas turbine intakes**

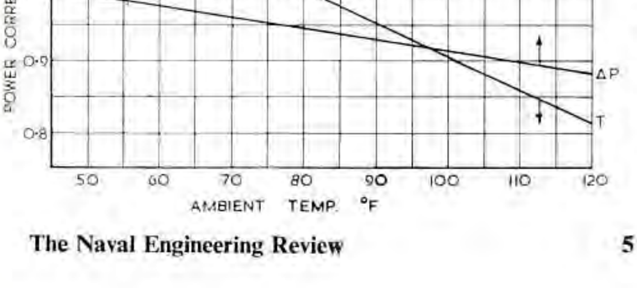
The problems involved, including filtration, silencing, intake cooling, pressure, boosting and construction

Compared with other forms of prime mover the gas turbine uses considerably more air per unit of power produced. It is necessary to dilute the high temperature products of combustion with sufficiently relatively cool compressor delivery air to prevent turbine blade temperatures reaching unacceptable limits. A typical simple cycle machine inhales some 15 lb/sec per MW which is more than three times the comparable figure for oil engines and steam plant in which fuel/air ratio is much nearer the stoichiometric.

Such high specific air requirements have the practical effect of making performance highly sensitive to mass flow and therefore to intake pressure loss and temperature. The effect of these two parameters on power output is important for most projects, although their influence on thermal efficiency also is not to be overlooked. Fig 1 indicates the order of adjustment to be made. Changes in relative humidity without corresponding movement in temperature have little effect on performance and are therefore customarily ignored.

**Gas & Oil Power, November/December 1970*

Fig 1. Typical power correction lines for intake pressure loss and temperature. The temperature correction is based on a reference point of 80°F



One design objective for an intake system, assuming that all the available power can be used, must be the reduction of total head pressure loss to a practical minimum. In certain cases, it may prove beneficial to boost intake pressure by the employment of booster fans.

Where conditions are suitable the normal de-rating due to temperature can be significantly offset by the installation of intake coolers.

As well as the simple conveyance of air to the compressor intake through suitably sized ducting, and the possible provision of equipment such as booster fans and coolers, an intake system must include a means of filtering the air to an acceptable standard and must also provide a degree of attenuation of the high noise levels emitted by the compressor. A brief review of the considerations affecting the choice of intake equipment is the subject of this article.

Filtration

Gas turbines are, within reason, largely insensitive to the presence of solid particles in the air stream. Nevertheless it is necessary to reduce fouling to an acceptable rate and avoid erosion of the compressor blading. It is recognised that these effects cannot be entirely eliminated in an hostile environment but long blade life and reasonable periods between compressor cleaning operations can be ensured by the proper selection of equipment.

Airborne dust particles can vary in size from less than one micron to several hundred microns in equivalent diameter. Fortunately, the larger sizes do not rise very far above ground level and both particle size and dust concentration diminish sharply with height.

It is generally accepted that particles above 10 micron will cause erosion of compressor blading and particles below five micron are more likely to cause deposition. It is therefore important to remove a high proportion of the large particles and, although most compressors can be cleaned in service without off-loading the turbine, the removal of small particles is also desirable.

Reliable data on particle size distribution and dust

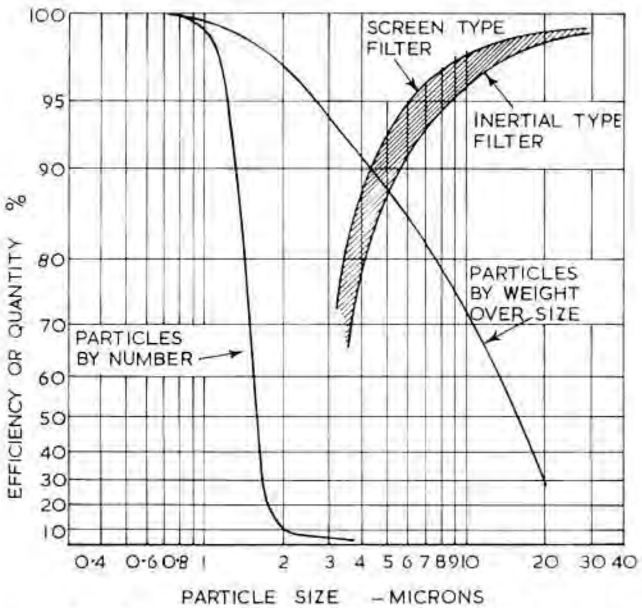


Fig 2. Dust particle size and weight distribution for an "average" atmosphere and efficiency range for typical gas turbine filtration equipment

concentration are often difficult to obtain for a prospective site, so reliance must be placed on assumptions which can be made from available information relating to similar environments. Table 1 and Fig 2 give an indication of typical conditions. It will be noted that the smaller particles are numerically predominant.

Fig 2 also indicates performance for typical filter types from which it is evident that efficiency drops sharply below the five micron region. It is therefore obvious that most of the airborne dust particles will in fact pass the filters but large, eroding particles will be captured.

Three basic filtration methods are in general use in gas turbine installations. One employs static panels or moving screens of fibre or paper media impregnated with an adhesive; these are discarded when loaded. The moving screen is constructed rather like a roll film arrangement in a camera, the media being moved automatically by a control which is sensitive to pressure drop or operates from a timer. Both the static panels and used rolls can be changed without shutting down the turbine.

A second method is similar to the first, except that the medium is a metal mesh which can be washed in oil. The panels of the moving screen version are cleaned automatically as they pass through an oil bath at the base of the unit.

The third separates the particles on an inertial principle and these are entrained in a proportion of the intake air (usually 10 per cent) which is discharged to atmosphere at a suitable point. The principle is illustrated in Fig. 3.

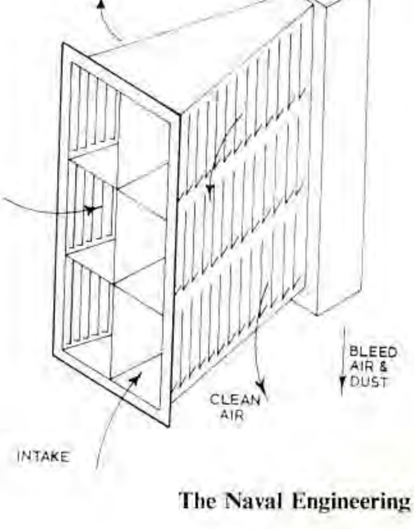
The automatic moving screen types are the most popular and are probably the best choice where dust concentrations are not high but where fine material predominates. For locations having high concentrations and large particle sizes, i.e. where moving

Table 1 Particle size range for various examples of dust types.

TABLE 1

Example of type of dust	Particle size range (micron)
Carbon black	0.01—0.03
Smoke e.g. burning oil Permanent atmospheric dust	0.01—1
Sea salt	0.03—0.5
Flour	1—80
Coal dust Fly ash	1—200
Cement dust	3—100
Pulverised coal	3—500
Plant spores Pollen	4—100
Fine sand	20—200
Hair	30—200

Fig 3. Inertial filter element capable of passing approx 2 lb/sec of air for a frontal area of 0·85ft². Bleed air is 10 per cent of the inlet mass flow



screen filters could easily become overwhelmed, the inertial type can be justified. Where concentrations are particularly heavy and yet a large proportion of the dust is of small size, as is typical of some Middle East situations, it may be necessary to install inertial and media type filters in series.

The difference in efficiency between the two types of moving screen filters is very small. Choice therefore is a matter of economics. Oil wetted types are three to four times more costly than dry roll types but maintenance material charges are confined to oil make up at small annual cost. Dry rolls have to be replaced at intervals depending on the dust concentration and mode of operation of the plant. For base load duty in dirty atmosphere, media replacement costs per annum can approach the first cost of the filtration equipment. For peaking plants and clean environment, the dry roll version becomes economically attractive.

Application of the inertial filter which costs much the same as the oil wetted moving screen type will depend on the sort of contamination as explained earlier. It does have the advantage of negligible maintenance material costs, the only parts requiring attention being the bleed fans. There is a small power requirement for driving the fans amounting to approximately 0.1kW per lb/sec turbine intake air.

For the oil wetted type of filter, face velocity at any point on the screen must be kept below 400 ft/min to prevent oil carryover on to the compressor blading. This is important as oily blading will efficiently capture the fine dust particles passing the filters and rapid fouling will ensue.

Mean face velocities for dry media filters can be 500 ft/min without loss of efficiency. Approach velocities for inertial filters can be 1,200 ft/min or more, which results in a significant reduction in face area and therefore filter house construction cost. Account must be taken, however, of the bleed flow which is additional to the turbine requirement.

Pressure losses associated with the velocities mentioned above are 0.4in w.g. and 0.5in w.g. for the oil wetted and dry roll types respectively. The efficiency of inertial filters increases with pressure drop. A practical figure combining reasonable efficiency with acceptable turbine power loss is about 1in w.g.

All screen type filters are subject to total blockage. Examples are icing up under certain combinations of air temperature and relative humidity and heavy dust loadings resulting from desert storms. If damage to the intake system is to be avoided due to the high suction pressures which would result, it is necessary to install automatic by-pass doors normally kept closed under gravity.

Under ambient conditions of high humidity and incidence of rainfall, water drop out on the filter screens is a possibility and this will flood oil out of the sumps of oil wetted filters. A syphonic water drain arrangement will deal with this problem.

For oil wetted filters, choice of oil viscosity is important. Too thin an oil will encourage carryover whereas high viscosity oil will interfere with automatic element washing. Sump heaters may be necessary where large changes in air temperature or very high dust loadings are experienced.

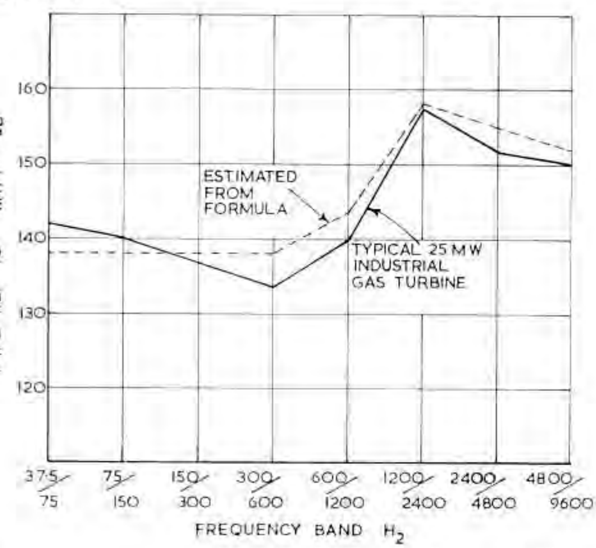
Silencing

The predominant source of noise in a gas turbine is the compressor. The sounds are generated by the individual blades passing stationary members and by turbulence of the high velocity air steams. A typical noise spectrum is given in Fig. 4 from which it can be seen that broad band noise is present together with substantial peaks in the 2,000 c/sec region.

As well as being at a generally high level, intake noise also has a high annoyance value because the human ear finds low frequency noise at a given dB level more readily acceptable than noise at high frequencies. This situation is clear from a comparison of Fig. 4 with the equal disturbance curves reproduced in Fig. 5.

Whilst some installations may do without any form of intake silencing owing to their remote location away from any form of habitation, it is obvious that by far the majority of installations will require a silencer. The introduction of a silencer in the air stream results in a pressure loss and hence a turbine

Fig 4. Typical and estimated noise spectra for an unsilenced compressor intake of a 25mW industrial gas turbine



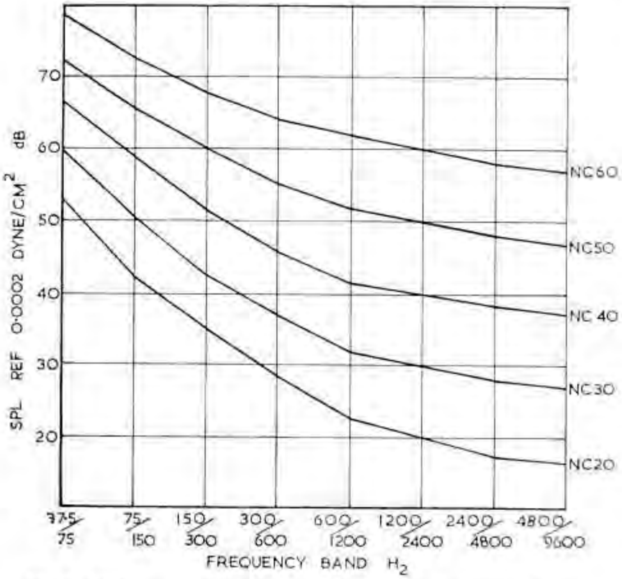


Fig 5. Noise criterion curves of equal disturbance. The human ear is less affected by low frequency sound

Environment	Typicar target noise levels at 1000 C/S dB Ref 0.0002 dynes/cm²
Urban district at night	28
Inside private dwelling	33
School classroom	33
Commercial area, daytime	38
General offices	40
Light manufacturing area	47
Heavy manufacturing area	53

Table 2 Typical acceptable noise levels for acoustic design purposes. Actual acceptable noise levels for a particular area will depend on existing levels, proximity to traffic and other prevailing factors.

power loss. It is therefore necessary to design for a specified duty and no more. The installation of silencers which reduce noise levels well below existing background or socially acceptable levels results in unnecessarily high installation costs and/or power loss penalty.

At many locations, background noise data or maximum noise level requirements may not be readily available. These will then have to be estimated from known information relating to similar environments. Table 2 sets out some typical acceptable noise levels.

If the sound level of the noise source is unknown, it can be estimated from the following formula:

$$PWL = 137 + 10 \log_{10} M$$

where PWL = Sound power level re 10^{-13}W
M = Gas turbine mass flow, lb/sec

For noise analyses, a noise spectrum is necessary. This can be derived from the result of the above formula by subtracting the following dB values to arrive at the PWL at each mid-frequency band (Table 3):

The Sound Pressure Level (SPL) at a given listening point depends on the distance from the noise source, the position relative to the initial noise direction, contributions from other noise sources, and reflections or damping due to adjacent buildings. Each situation requires a detailed analysis but an approximate idea of the attenuation which the silencer is required to provide can be obtained from the addition or subtraction of dB values to or from the source PWL based on the following rules:

1. *Attenuation due to distance:*
   Subtract $20 \log_{10} d + 8$ where d = distance from noise centre in ft.
2. *Effect of directivity:*
   See Table 4.

TABLE 3
Frequency band, cycles/sec

Mass flow lb/sec	37·5 75	75 150	150 300	300 600	600 1200	1200 2400	2400 4800	4800 9600
100	35	35	35	35	30	10	3	0
200	30	30	30	30	25	10	5	8
400	25	25	25	25	20	5	8	11

Table 3: Frequency correction factors for use with the formula PWL — $137 + 10 \log_{10} M$. The dB values are to be subtracted.

TABLE 4

Angle degrees	Frequency band, cycles/sec							
	37·5/75	75/150	150/300	300/600	600/1200	1200/2400	2400/4800	4800/9600
0	9	9	9	9	9	10	10	10
45	5	5	6	6	7	7	8	8
90	—3	—7	—8	—9	—10	—11	—12	—13
135	—5	—9	—10	—11	—12	—13	—14	—15
180	—5	—9	—10	—11	—12	—13	—14	—15

TABLE 5

Difference between noise levels dB	0	1	2	3	4	5	6	7	8
Amount to be added to higher noise level dB	3	2·5	2	2	1·5	1	1	1	0·5

3. *Addition from other noise source:*
See Table 5.

If more than one additional noise source is to be taken into account use the table for each one in turn.

The damping or reverberant effect of adjacent buildings, if likely to be significant must be the subject of detailed analysis too extensive to be dealt with here.

Table 6 is an example of SPL estimation using the above technique. It must be emphasised that this procedure will give only a rough guide and detailed acoustical investigation is recommended wherever possible.

It will be noted that the attenuation required from the silencer is greatest at the higher frequencies which is a natural result from the previous comparison of the typical noise source characteristic Fig 4 and the noise criteria curves Fig 5.

The type of silencer best suited to this requirement comprises a number of parallel sound absorbent panels, known as splitters, which are set in line with the air stream. A group of such panels is inserted in the air intake duct as near as possible to the compressor intake. They are made from perforated sheet material, suitably stiffened and infilled with rock wool or similar absorbent material.

The silencer attenuation characteristic can be shaped to some extent by suitably choosing the thickness and spacing of the panels. Attenuation at any frequency of a given splitter configuration varies directly with length of splitter. In the medium to high frequency ranges, a silencer would provide between four and five dB alternatives per ft run of splitter assembly.

A silencer having the performance required for the example worked out in Table 6 would have a cross section area of about 150 sq ft and would be approximately 12ft long.

The pressure drop across a silencer for a given degree of noise level reduction is a function of its cross section area and a balance must be struck between cost of silencer and the penalty of turbine power loss. A typically acceptable figure is 1 to 1½in wg.

Intake cooling

From Fig 1 it can be seen that a high intake temperature results in a significant loss in power output, i.e. about 0.5 per cent per degree F. Where high temperatures are associated with medium to low humidities, for example in many desert areas, a proportion of this loss can be readily regained by the introduction of an evaporative cooler in the intake system.

The construction of a typical cooler comprises two vertical panels of fibre mat elements through which the air is drawn at right angles. The upstream panel is kept in a suitably moist condition by means of numerous fine sprays and the downstream panel acts as a mist extractor. Beneath the cooler a sump is sometimes provided into which water drains from the elements and from which the water is re-pumped to the nozzles.

Although droplet carryover to the compressor is kept as low as possible by suitable cooler design, and by limiting downstream relative humidity, some such carryover is inevitable and any impurities will dry out on the blading. Over a period of time, the deposits will reduce compressor efficiency and may be difficult to remove without stripping down. It is therefore highly desirable to use high quality distilled water in order to avoid a deposition problem.

Water consumption due to evaporation will depend on intake air temperature and humidity but a typical maximum figure is one gallon per ton of air mass flow.

To prevent condensation at the compressor inlet it is desirable that the downstream relative humidity is kept below 80 per cent. Therefore, where ambient humidities are approaching this figure or are higher, an evaporative cooler is of no advantage. It should be noted however, that high humidities at high inlet temperatures are unusual even at coastal sites.

Cooler efficiency is defined as follows.

$$n = \frac{Ti - To}{Ti - t}$$

where T = Dry bulb temp.
t = Wet bulb temp.
i = Inlet
o = Outlet

TABLE 6

Noise level dB	Frequency band, cycles/sec							
	37·5/75	75/150	150/300	300/600	600/1200	1200/2400	2400/4800	4800/9600
Source PWL re 10^{-13}W (Fig 4)	141	140	137	134	140	158	151	150
Frequency Correction (Table 3)	—26	—26	—26	—26	—21	—6	—7	—10
Directivity Correction for 45° (Table 4)	5	5	6	6	7	7	8	8
Attenuation due to distance for 200ft ($-20 \log_{10} d$-8)	—54	—54	—54	—54	—54	—54	—54	—54
SPL at 200ft re 0·0002 dyne/cm²	66	65	63	60	72	105	98	94
Addition for two similar noise sources (Table 5)	3	3	3	3	3	3	3	3
Total SPL at 200ft	69	68	66	63	75	108	101	97
Target noise level at 200 ft (NC40 Fig 5)	67	59	51	46	41	40	38	37
Silencer Attenuation required for each noise source	2	9	15	17	34	68	63	60

Table 6: Calculation of intake silencer requirements for two typical 25MW industrial gas turbines to meet Noise Criterion 40 at an average distance of 200ft and angle of 45° to the primary noise direction from each machine. Note adjustment may also be required to take account of noise emitted from the exhaust stacks and also reductions due to attenuation properties of intake ducting and equipment.

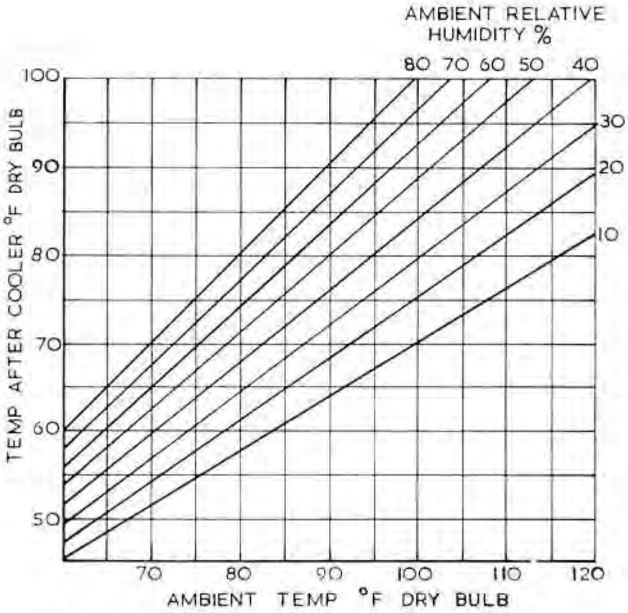
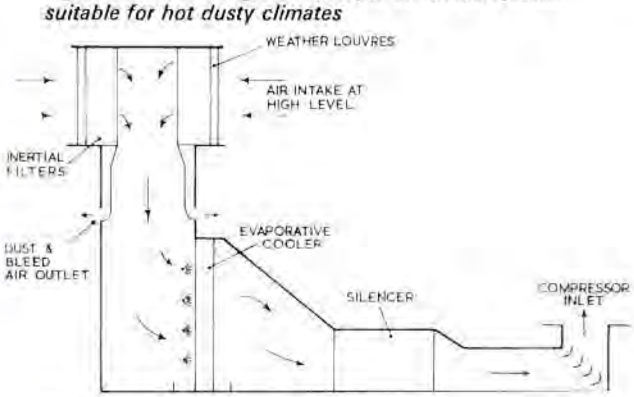


Fig 6. Effect of evaporative cooling. The chart is based upon a cooler efficiency of 80 per cent and a maximum relative humidity after the cooler of 80 per cent

A unit of practical size would be capable of an efficiency of around 80 per cent and the decrease in compressor inlet temperature which can be gained with such a cooler and limiting the RH to 80 per cent can be read from Fig 6.

The face velocity of a typical 80 per cent efficient cooler is approximately 400 ft/min which gives a face area of the same order as that required for screen type filters.

Fig 7. Section through an example air intake system suitable for hot dusty climates



Insertion of the cooler in the air stream introduces a further pressure loss thus offsetting slightly the gain due to reduced temperature but as a practical pressure drop is 1.2 in wg this in effect cancels only the first 2° of temperature drop.

Pressure boosting

Since a pressure loss results in a turbine power loss, it follows that an increase in compressor intake pressure above barometric will produce a power bonus. The possibility of squeezing more power from a given unit by supercharging in this manner is technically feasible as proven by the several installations incorporating this feature which have been built during the past five years. Economic feasibility is not a foregone conclusion but there are situations in which a case can be made particularly where a high price can be placed upon the extra power gained.

Any worthwhile degree of pressure boosting will be accompanied by a temperature rise and some of the gain due to increased pressure is thus lost if some form of aftercoding is not employed. Where humidity conditions are suitable, the evaporative type of cooler described earlier is ideal for this purpose.

The increase in pressure is achieved by means of a forced draught fan, either motor or steam turbine driven, if the plant has an exhaust heat boiler. Fans of a suitable type for this purpose tend to be noisy and additional silencing treatment would almost certainly be required. Furthermore, if the availability of the plant is not to depend on the fan, some form of by-pass may be necessary.

A weather louvre suitably designed to provide a degree of sand removal is placed at the aperture followed by inertial filters. The overall total head pressure loss for such a system might total 3.9in wg arrived at as follows:

	in wg
Intake louvres	0.2
Inertial filters	1.2
Cooler	1.2
Silencer	1.0
Ducting	0.3
	3.9

References:

"Gas Turbine Sound and Its Reduction" NEMA Pub. No. SM33—1964

"What to do About Gas Turbine Noise" ASME Paper 63—AHGT—77.

Stabilised sighting systems for guided missiles

The Avimo-Ferranti AF.120 Stabilised Sight fitted to a "Scout" helicopter

During the 1950s a new form of weapon appeared —the line-of-sight guided-missile. This weapon was designed to be used against an enemy who was visible to the human eye. It was designed against a requirement of inaccurate range estimates and was required to be of lightweight construction, cheap to produce and, above all, be accurate in use. The technique envisaged was that of guiding the missile after launch into a position where it was in-line, and remained in-line, with the intended target. In order to assist the aimer/operator in this task, the missile is fitted with a flare which appears to the aimer as a spot which diminshes in size and brilliance as the missile proceeds down range towards the target. The aimer/operator's task, therefore, is to keep the spot of light in a position where it interrupts his view of the target and then, irrespective of the range of target, (provided it is within the operational range of missile), a "hit" will occur.

Earlier line-of-sight guided-missiles such as the "Vigilant" were used for relatively short ranges of 1,000 to 1,500 yards. At these ranges it was at first thought that no optical assistance would be required. Early experiments showed, however, that beyond about 800 yards optical assistance did improve the capability and consequently simple monocular optical aids were fitted to the aimer/operator's control stick. The technique involved at that time the aimer/operator placing one eye against the monocular eyepiece and use of the other eye for "gathering" the missile, taking advantage of the wider field of view of unity vision. When the missile was judged to be inside the field of view of the monocular, concentration of vision was then focussed through the monocular and the missile was steered onto the target.

This situation was perfectly satisfactory until once more advancing technology demanded the guidance of line-of-sight missiles from a moving vehicle, ship or aircraft. Once mounted on a moving vehicle the problems are increased manifold. It is no longer enough just to see the enemy target. In order to make maximum use of the weapon under his control, the aimer/operator of the missile will need to know if the distant target is of a hard- or soft-skinned nature, whether it is static or moving and what kind of armament it carries. Another basic reqiurement is for the aimer to be able to observe the surrounding terrain or water over a wide arc. When firing from a moving vehicle, the aimer/operator is strapped to his seat and therefore it must be necessary for his sighting system to be stabilised over a wide arc of vision without altering the fore and after alignment of the sight's eyepieces. In addition, the spurious movements of a vehicle, ship or aircraft have to be catered for. Thus, the need for a gyro-stabilised sighting system arose which Ferranti and Avimo jointly developed. Designated the AF.120 stabilised sight Ferranti were responsible for the electro-mechanical components and Avimo the optical system.

The AF.120 stabilised sight

Basically the sight is a gyro-stabilised telescope fitted with a binocular eyepiece. It is designed to provide an effective means of surveillance to enable the identification of a target and to provide a visual aid for the guidance of missiles to targets at ranges of up to 10,000 metres (approx 11,000yd) from moving vehicles.

The main feature of the Avimo-Ferrranti sight is the magnification of the viewed stabilised image. Two magnifications are available:

1. Low magnification with a large field of view.

2. High magnification with a small field of view.

A thumb-operated switch on the tracking control handle is used to select the required magnification. An electrically driven gyroscope directly controls the mirror. This stabilises the sight line against pitch and yaw motions of the carrying vehicle, any movement of the vehicle in roll only causing apparent rotation of the image.

One feature of the AF sight is the automatic image tilt correction. In any periscopic arrangement, rotation of one mirror about a vertical axis causes an apparent tilt of the viewed horizon. In the AF sight this is corrected by a servo driven prism system which maintains the viewed horizon horizontal during yaw motions of the vehicle.

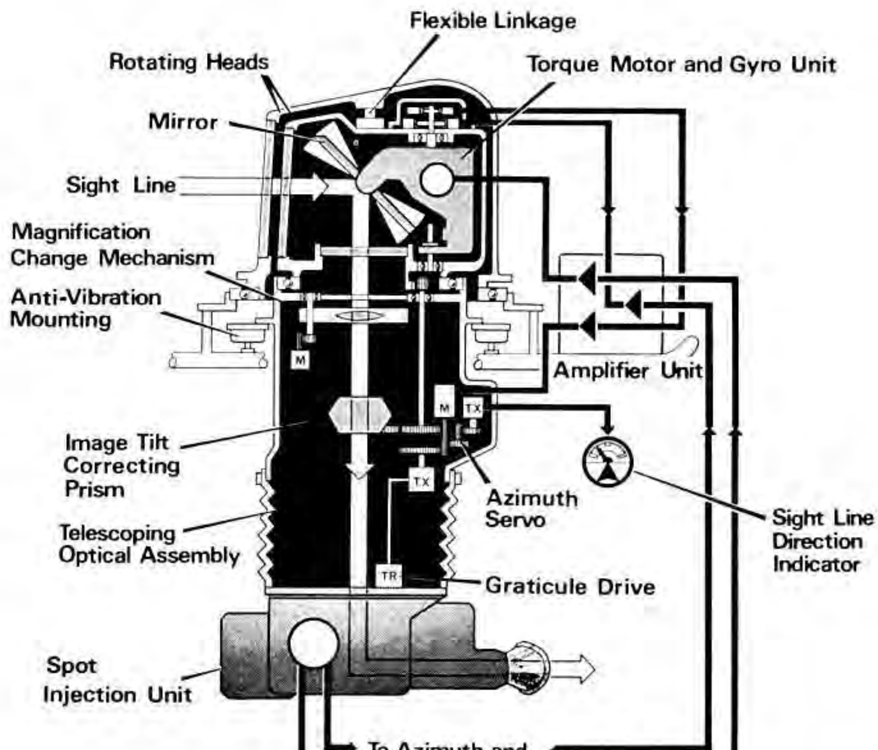
Since the mirror is electrically controlled a variety of configurations and positions to satisfy particular customer requirements is possible.

The binocular eyepieces remain in a forward looking direction at all times. In both axes, azimuth and elevation the rate at which the mirror scans is related to the magnitude of movement of the tracking control handle. The scan rate is thus directly controlled by the operator.

A stream-lined rotating head at the top of the sight protects the inner head assembly from buffet-

TYPICAL CHARACTERISTICS

Magnification:	x 2.5: x 10
Fields of view:	$\pm 20°$ (x 2.5); $\pm 5°$ (x 10)
Deflection of the field of flow:	$\pm$ **60°** azimuth 60° elevation (total)
Tracking rates: azimuth, low magnification:	up to 18°/sec.
azimuth, high magnification:	up to 4°/sec.
	elevation up to 4°/sec.
Total exploration field with stationary eye piece:	azimuth 140° maximum elevation 80° maximum
Eyepiece:	Binocular ($\pm$ 5mm exit pupil)
Interpupillary distance:	56 to 72 mm
Independent eyepiece focusing:	–5 to +2 dioptres
Vertical adjustment:	Infinitely variable over $4\frac{5}{8}$ inch distance



Schematic diagram of the Avimo-Ferranti AF.120 Stabilised Sight.

The Westland "Scout" helicopter fitted with Nord (now SNIAS) SS.11 wire-guided missiles and the Avimo-Ferranti AF.120 Stabilised Sight. The Sight's rotatable head can be seen projecting through the helicopter's canopy

ing by external forces and also ensures that an optically acceptable window is provided at the correct angle to accept the incoming top mirror image. This window is fitted with an electrically driven wiper together with demisting and washing facilities.

The sight line azimuth axis, relative to the vehicle's fore-and-aft axis, is displayed in two ways. A servo driven graticule displays sight line information for the operator. A small indicating instrument displays the same information for other members of the crew.

The interpupillary distance of the binocular eyepieces is adjustable. Independent eyepiece focusing is also provided. A soft rubber pad surrounds the eyepieces providing comfortable operation and affording operator protection in the event of rapid deceleration.

The sight installation usually comprises a supporting frame which incorporates an anti-vibration mounting system to isolate the sight optics from the high frequency vibration component present in most vehicles. This frame also carries the electronic power supply unit, system switches and washer reservoir.

Future developments

A new lightweight stabilised sight is currently under development. The new sight is a logical development from, not an extension of, the highly successful AF.120 series. It will weigh considerably less, be smaller, and will be of modular construction which will permit its use in a wide variety of helicopters and land and sea vehicles. The lightweight sight will contain the spot injection unit of the field simulator and, as an optional additional feature, image intensifier equipment or if required, laser range finding facilities.

Sea trials of the vertical take-off Harrier ground attack aircraft

Trials of the vertical take-off Harrier ground attack aircraft recently took place on board the aircraft carrier H.M.S. *Ark Royal* in the Moray Firth. The purpose of the trials was to further evaluate the Harrier under operational conditions and so assist in assessing its potential in the maritime role. The Harrier trials were carried out on board the aircraft carrier H.M.S. *Eagle* earlier this year.

Harriers from No. 1 Squadron, RAF, took part. They have been practising for a series of trials from aircraft carriers using a simulated deck painted on a runway at RAF Wittering, near Peterborough, Northants.

This will be the second time since the war that an operational RAF squadron has flown off an aircraft carrier, the first being No. 209, equipped with Single Pioneers, during the Malaysian-Indonesian Confrontation.

Electronics speed control of steam turbines[*]

by D. Becraft and S. L. Harrison†

Aircraft-derived equipment applied to recent important ships

Electronic control systems have been in use for many years in the aircraft industry and are now finding applications in the marine gas and steam turbine field. Ultra Electronics Ltd, of Western Avenue, London, W.3, acknowledged world leaders in electronic engine control and protection, have recently provided UEL systems for a number of new ships including the *Esso Northumbria*-class 253,000 tdw British-built tankers and Cunard's *Atlantic Causeway*-class container ships.

One of the first applications in marine turbine control has been the introduction of electronic overspeed protection systems. Electronic systems offer many advantages over mechanical protection systems. Accuracies are usually better than 1 per cent of turbine rated speed and very rapid response is possible, enabling an overspeeding turbine to be protected far faster than mechanical systems allow. The system is also very simply reset, either automatically as the turbine runs down to a predetermined speed or manually. Other advantages include easy trip point adjustment, the ability to use several channels in a multiplex equipment to improve the integrity of the system, and the provision of electrical outputs for remote indication. A further advantage of an electronic system is that it can be tested with the turbine on-line, but without the need for physically overspeeding, as is the case with a mechanical system. This is performed by electronically depressing the trip datum to a level below the normal running speed of the turbine. In a simplex protection system this would lead to a trip condition, whilst in a multiplex protection system each lane could be tested in turn without causing an apparent overspeed condition

Electronic overspeed switches can be fitted very easily to new or existing installations. All that is required is a pulse probe magnetic transducer fitted in close proximity to a suitable gear wheel driven from the turbine shaft. Any existing gear can be used provided it is made of a ferrous material and that the passing frequency of the gear teeth at 100 per cent rated speed lies between 1 KHz and 20 KHz.

The pulse probe signal is fed to the electronic control box which may be mounted in any convenient position. The control box continuously monitors the turbine speed and if the pre-determined trip level is reached a relay is operated, the contacts of which can be used to operate steam shut-off valves or initiate any other required action. Further contact sets can be made available for a central warning system and hence faults in one part of a multiplex equipment can be isolated with minimum risk or disturbance.

Philosophy of overspeed protection systems

The use of duplex, triplex or other redundant systems can greatly improve the overall safety level and protection of systems. The level of protection obtained depends upon a number of factors such as:

(a) the degree of redundancy employed
(b) the presence or absence of a fault warning system
(c) the intervals at which the equipment is checked
(d) the use of power supplies in a fail-safe manner
(e) the reliability of its component parts

For the present purposes the following is assumed:

(i) no redundancy exists except in the electrical parts
(ii) power supply failure leads to automatic tripping
(iii) no fault warning arrangements are contemplated
(iv) the electrical equipment is checked once a week

This leads to a relatively straightforward analysis of the effects of electrical redundancy. Consider first the "risk factor". This is estimated as the proportion of time for which the protection system is danger-

*Marine Engineer and Naval Architect, November 1970.
†Ultra Electronics Ltd.

ously inoperative due to electrical faults. If we have no overspeed protection system, the risk factor is unity. If we have a simplex system the factor may be about 1 per cent, indicating that only one in a hundred potential overspeeds would not be picked up by the electrical system. The reciprocal of the factor is a measure of the improvement to be expected from fitting the system, as compared with operating without protection. In practice this factor has to be combined with another for the non-electrical parts of the system, but except in the case of common physical damage it is permissible to consider them separately.

The basic fault rate for a single lane of electrical circuitry is very pessimistically taken to be two per year. It is not feasible to introduce fail-safe principles to any extent in the circuit itself, so roughly half the faults would give a "nuisance" trip, the other half leaving the system unprotected. If a weekly check is made the longest possible time the machine remains unprotected is one week.

Simplex protection. Here we are concerned with the possibility that the single electrical protection "lane" fails in the unsafe direction, and that, before the next weekly check is made, an overspeed condition occurs. The appropriate "risk factor" for the system is then:

$$\tfrac{1}{2} \times 1/52 \times 1 = 1/104$$

ie, whatever the risk of an overspeed in the absence of any protection, the risk is made 104 times smaller by the protection system. The $\frac{1}{2}$ arises because we are not interested in including those occasions when the overspeed condition occurs *before* the electrical failure, as this is not dangerous.

The 'nuisance' trip rate for the simplex system is roughly once per year, using the same pessimistic

Schematic diagram of twin-duplex overspeed switch

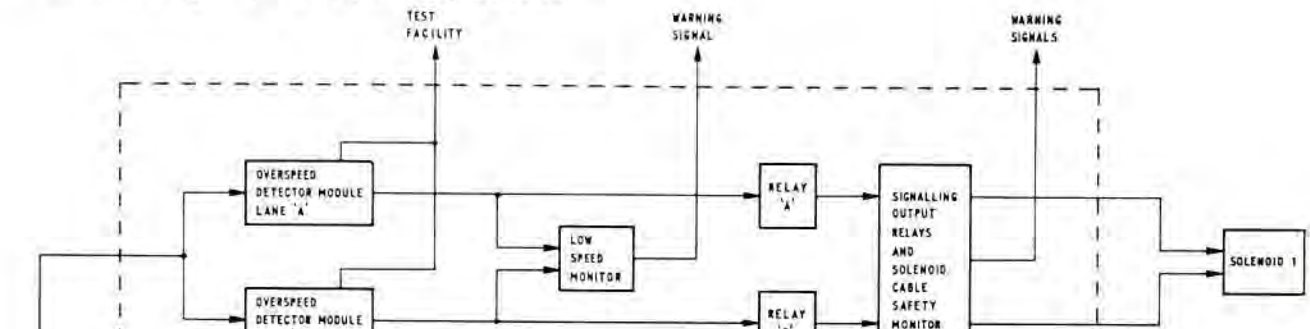


figure of two equipment failures per year.

Duplex system. Here the outputs of two electronic protection lanes are combined to produce a trip action if either lane so commands. The "risk factor" now reduces to

$$\tfrac{1}{3} \times 1/52 \times 1/52 \times 1^2 = \frac{1}{8100}$$

where the $\frac{1}{3}$ arises in a way similar to the $\frac{1}{2}$ in the simplex case. The risk of unprotected overspeed is now very much reduced, but the "nuisance" trip rate has doubled to twice per year. During repair of most faults, simplex protection can be maintained.

Triplex and twin duplex system. If the safety obtainable from a duplex system is adequate but the "nuisance" trip rate too high, this objection can be overcome by a "Majority Vote" type of triplex arrangement, in which one faulty lane is automatically overriden by two healthy ones in a logical combination of the individual lane outputs. The addition of the third lane makes the triplex system three times worse than the duplex system on risk factor, but very many times better in regard to nuisance trips.

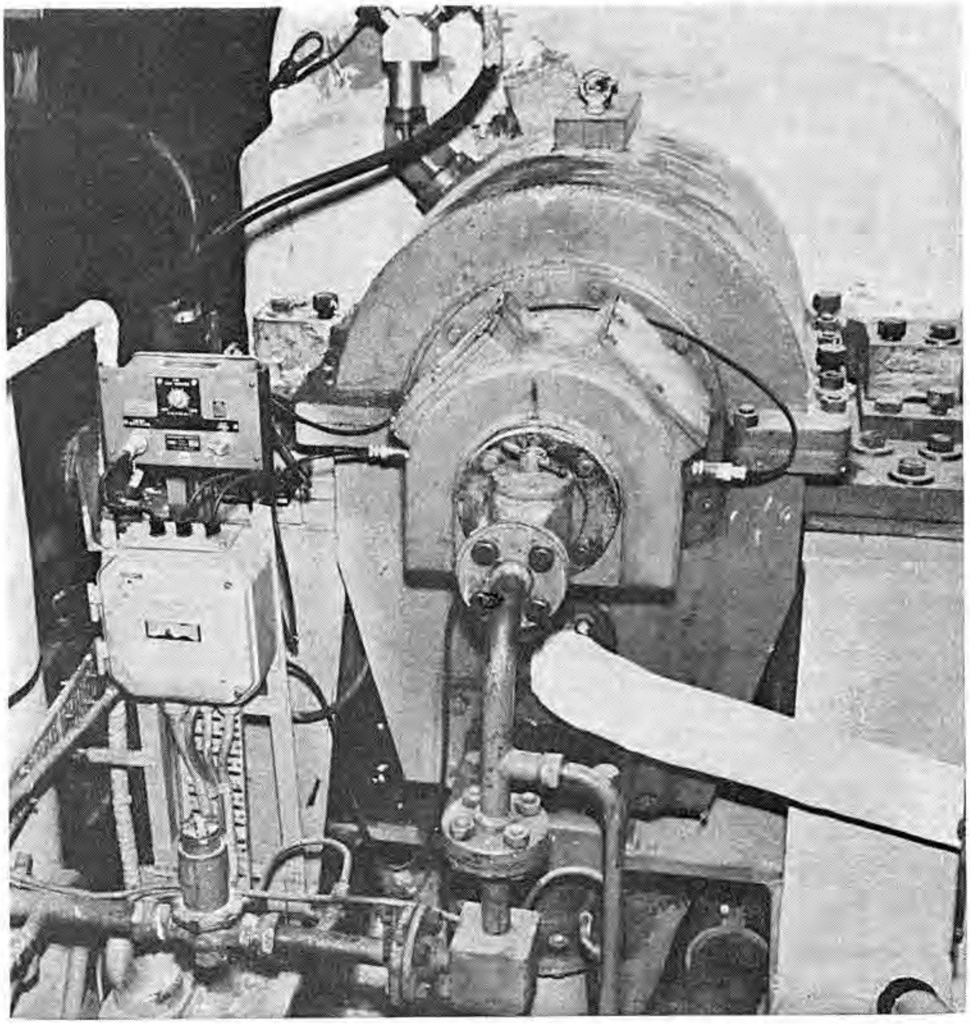
Twin duplex systems provide a further attractive alternative especially where two power supplies are available. Two identical duplex channels are used with the following logic:

Trip *If either*

Lanes A and B of Channel 1 command

or

Lanes A and B of Channel 2 command



UEL overspeed trip panel alongside forward hp turbine pedestal—EE-AEI 32,000hp turbines of 'Esso Northumbria'

This system gives much the same low risk factor as the duplex system with a very low nuisance trip rate.

Fault warning. It is normal to make use of any discrepancy that occurs between lanes when a fault is present, to put up a fault warning. Since equipment known to be faulty can generally be replaced quickly, the fault warning system makes possible a considerable reduction in risk factor, full redundancy being soon restored instead of waiting until the next system check. If repair or replacement takes as much as half a day, a monitored triplex system is still five times safer than a duplex system. With the twin duplex system the faulty channel can be removed leaving a duplex system with much the same risk factor as a simplex system but with a "low nuisance" trip rate, so maintaining a high level of safety while repairs are made. Arrangements can be made to enable a triplex system to revert to duplex operation while a faulty lane is being repaired.

Marine duplex overspeed switch

This system is designed to prevent overspeeding of marine steam turbines. It consists of two pulse probe signal sources sensing shaft speed from the same ferrous toothed wheel, the duplex overspeed switch, and the required output facilities. The duplex overspeed switch gives a trip signal when the turbine speed exceeds the datum level.

The unit consists of two identical overspeed lanes. The relay outputs of each lane are connected in series so that both lanes must indicate an overspeed condition before the output circuitry is activated. The input signal to the unit is obtained from two pulse probes, one per lane. Warning lamps indicate when each lane has tripped, and the output trip signal operates a solenoid valve which shuts off the steam supply to the turbine. Each lane can be tested in turn without activating the output circuitry. Solenoid circuit continuity and the power supply are monitored and any failure is indicated.

The trip point of the unit is adjustable between 110 per cent and 115 per cent of turbine running speed, by means of a calibrated potentiometer. The accuracy of the trip point is $\pm$ 1 per cent of trip frequency. The unit operates from either a 24V dc or a 48V dc power supply. This unit has been accepted by Lloyd's Register for use on board ships and a project has been initiated to obtain full LR approval.

Twin-duplex overspeed switch

This arrangement has been designed to prevent overspeeding of boiler feed pump turbines. The system consists of two pulse probe signal sources sensing shaft speed from the same ferrous toothed wheel, the twin-duplex overspeed switch, and the required output facilities.

The twin-duplex overspeed switch comprises two identical duplex channels. Each channel is separately housed and has an independent pulse probe signal input, solenoid valve outputs and signalling outputs. A 36-0-36V dc power supply is used, energising each channel with 36 volts taken from opposite sides of the supply. A 50V dc power supply is used to continuously energise each solenoid through its respective duplex channel. Within each channel the electronic overspeed detection circuitry is duplicated, and comprises two lanes A and B.

The pulse probe input signal is shared between the two lanes and the relay output from each lane is supplied direct through separate connectors and cables to the solenoid valve.

If two lanes of one channel agree that an overspeed exists, then a trip is caused by the action of the solenoid driven by that channel. This occurs without reference to the other channel and its solenoid.

The logic of the twin-duplex system is:

Trip *If either*
Lanes A and B of Channel 1 command
or
Lanes A and B of Channel 2 command

Relay contacts are available to operate lamps or flags to indicate the state of each lane. A further set of contacts are available for a computer monitor.

To guard against loss of the pulse probe input signal a monitoring circuit looks for excessive low speed output (30 per cent) from the detector circuit. This circuit also monitors the power supply. Relay contacts are available to indicate this low speed output.

To guard against an open circuit failure in the energising cables to each solenoid, a solenoid cable safety monitoring circuit is incorporated. The circuit monitors, all four leads from that channel to its solenoid and gives a relay indication when a fault condition is detected. The relay output is muted during a genuine overspeed trip.

The system is tested by a datum depression method, testing each channel in turn. The datum depression circuit reduces the trip datum to 60 per cent of turbine running speed enabling on-line tests to be made with suitable interlocking of the hydraulic system. The channel not under test continues to monitor the turbine in the normal way. The low-speed monitor can be tested by short-circuiting the pulse probe signal input.

In the event of one lane or channel developing a

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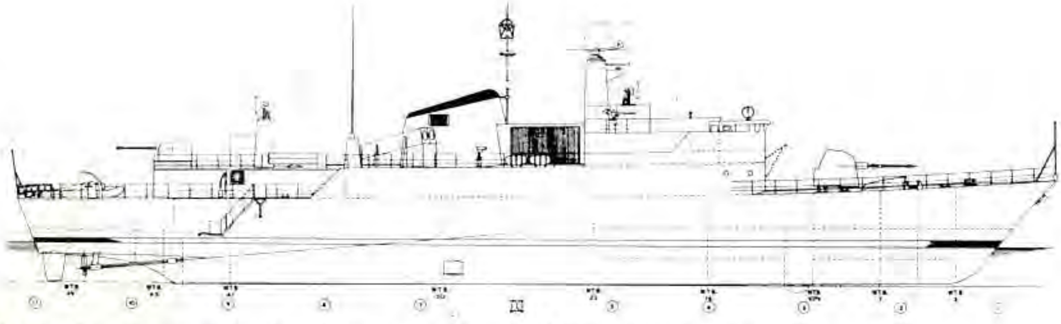


Typical general arrangement drawing of the Vosper Thornycroft Mark 8 fast corvette

Yet more Vosper Thornycroft Corvette designs

Outline designs for two completely new fast corvettes have been prepared by Vosper Thornycroft. These bridge the gap in the company's range which at present exists between the 600-ton Mark 3 corvette and the 1200-ton Mark 5 frigate. They are also designed for speeds intermediate between the 25 knots of the Mark 3 and the 40 knots of the Mark 5.

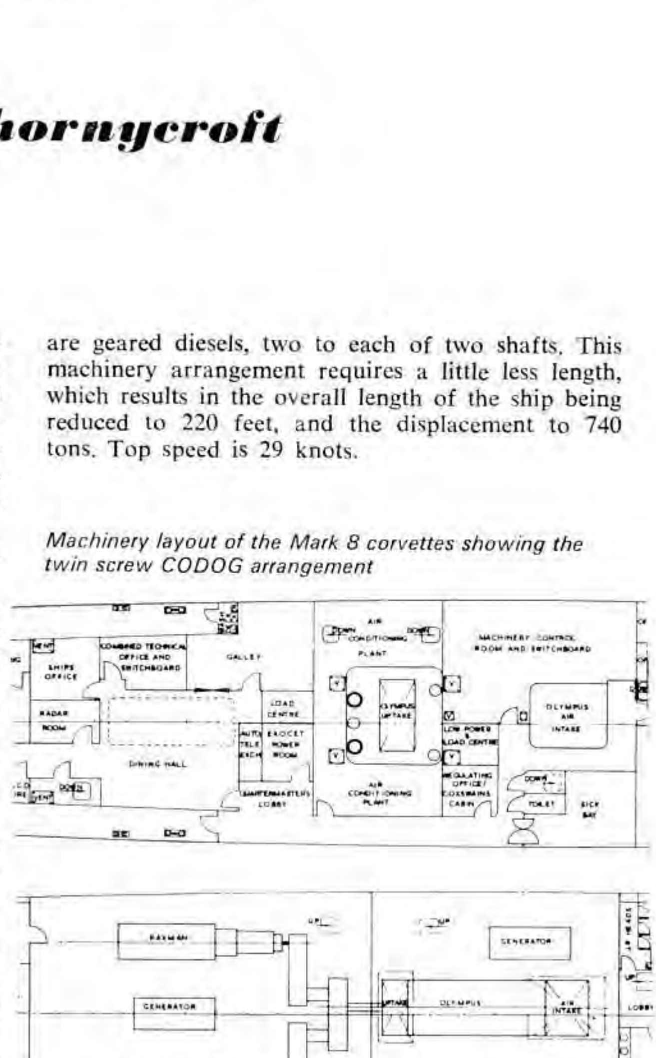
The Mark 8 design is for a ship 240 feet long, displacing 850 tons, with twin-screw CODOG machinery. This consists of one Rolls-Royce gas turbine driving both shafts through reduction gearing, for the top speed of 32 knots, with the alternative of Paxman diesel engines, one to each shaft, for speeds of up to 19½ knots. Cruising range at 16 knots is 3500 nautical miles.

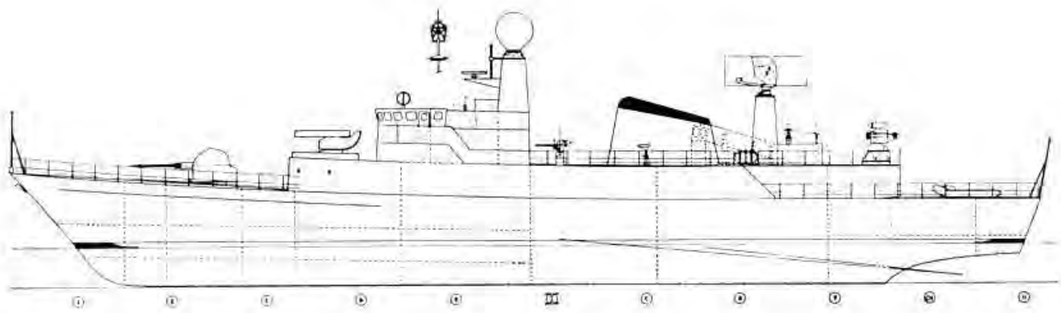
Typical armament

A typical armament for the Mark 8 would be an Oto Melara 76-mm gun, twin Oerlikon 35-mm gun, two Oerlikon 20-mm guns, two twin Exocet guided missile launchers and missile fire control system, Ferranti Selenia fire control and Ferranti action information system; two triple anti-submarine torpedo tubes and Plessey MS 26 sonar. Two 2-in rocket flare launchers are also included, and depth charge rails can be fitted if required. The Mark 8 is designed for a complement of 65.

The Mark 9 corvette is very similar to the Mark 8, the main difference being that the main engines are geared diesels, two to each of two shafts. This machinery arrangement requires a little less length, which results in the overall length of the ship being reduced to 220 feet, and the displacement to 740 tons. Top speed is 29 knots.

Machinery layout of the Mark 8 corvettes showing the twin screw CODOG arrangement





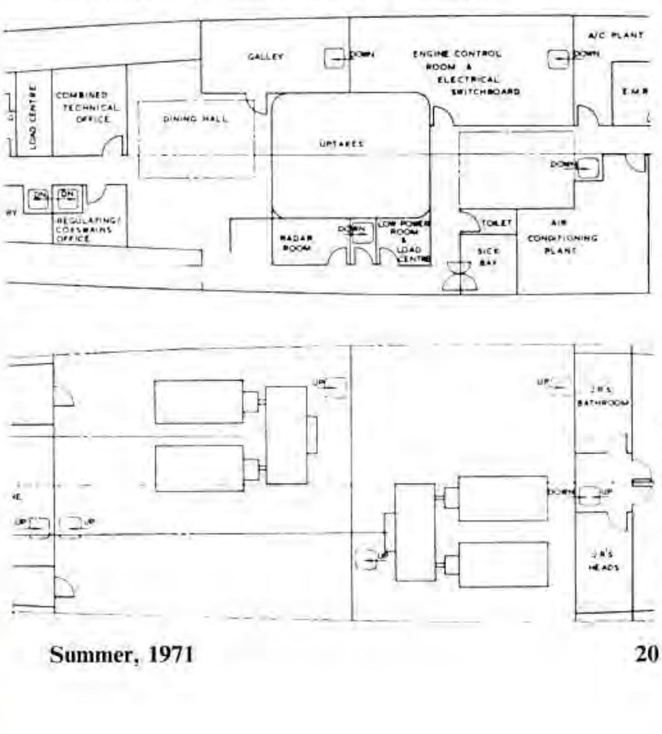
Typical general arrangement drawing of the Vosper Thornycroft Mark 9 fast corvette

Suggested armament for the Mark 9 is the Oto Melara 76-mm gun and triple Seacat launcher, both controlled by HSA fire control equipment; two single Oerlikon 20-mm guns, and Bofors 375-mm twin anti-submarine rocket launcher. Plessey MS 26 sonar is fitted. Accommodation is for a complement of 67.

As is normal in Vosper Thornycroft designs there is scope for variation in the armament within the overall weight limit of about 75 tons.

As compared with the frigate the corvette offers the advantages of much reduced first cost and maintenance and manning needs. By taking advantage of the latest developments in weapons and propulsion machinery Vosper Thornycroft have given these corvettes a very powerful armament and high speeds. Close attention has also been given to sea-keeping qualities, which are supported by the installation of the company's own stabilizer equipment. The new designs, based on Vosper Thornycroft's experience on what is perhaps the widest range of warships developed within a single company anywhere in the world, promise to provide powerful fighting vessels at modest cost.

Machinery layout of the Mark 9 corvettes showing the four geared diesels, two to each of two shafts



(Continued from page 18)

Electronics speed control of steam turbines

fault, the entire channel can be removed and replaced by a spare channel.

The trip point of the unit is set at 110 per cent turbine running speed, and can be internally adjusted between 100 per cent and 120 per cent turbine running speed. The accuracy of the trip point is $\pm$ 1 per cent of the trip frequency. This unit has been designed to meet the full requirements of the CEGB for electronic equipment and has been accepted as suitable by that organisation.

Other marine controls

The two overspeed switches previously described form a part of the range of turbine control and monitoring equipments that UEL currently supply for marine turbines. Other equipments include vibration monitors, turning gear control units and low speed switches. UEL are continuously expanding their range and amongst these new products are axial displacement monitors, electrical governors and other protection devices.

The Rolls-Royce Marine RB211 gas turbine

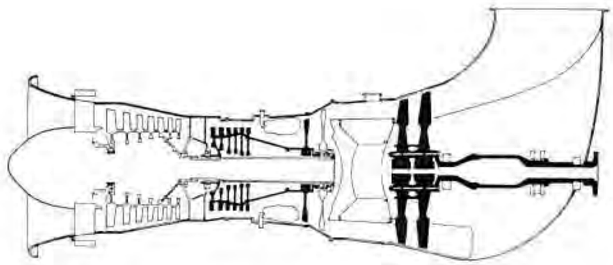
As development of the turbofan engine which powers the Lockheed Tristar aircraft was, until recently, expected to be available from 1973 onwards. Provided that the Tristar project goes ahead on a sufficient scale to render the marine version a viable modification (over 300 firm aero engine orders and over 200 engine options were booked at February 4, the date of the Rolls-Royce receivership) there seems a good likelihood of its becoming the European second-generation high power aero-derived propulsion gas turbine.

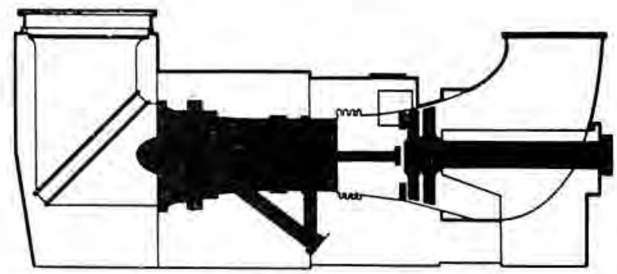
The marine conversion would be effected by using the third stage turbine which, in the aircraft version, drives the free fan, as the power turbine for driving the propeller. Improved blade materials and blade cooling techniques enable the aero version to run at Tmax = 1,500°K. Considerable interest has been shown by potential operators due to its improved performance and much lower air and gas flows at this first stage:

	Olympus	*RB211*
Maximum power hp	27,575	27,880
Specific fuel consumption lb (g/shp-h)	482 (219)	416 (184)
Maximum cycle temperature °K	1,190	1,365
Air mass flow lb (kg/sec)	233 (105.5)	193 (87.6)
Specific output hp/lb (kg) air/sec)	117 (53.1)	143 (64.8)

From the foregoing figures it will be seen that the specific output of the RB211 (hp per lb of air flow) has been increased by 22 per cent while the specific fuel consumption is only 85 per cent that of the Olympus.

The Marine RB211 would readily fit within the limits of the current TM3B Marine Olympus module, making possible an exchange in the future with uprated versions.





Section through a Rolls-Royce Marine RB211 gas turbine. The third-stage turbine in the TriStar drives the fan through the hollow concentric primary and secondary shafts. Below it is seen fitted in a TM3B module

Model ships ordered by MOD

An order for approximately 60 sets of ship models has been placed by the Ministry of Defence (Navy) with the Electronic and Display Equipment Division of Ferranti Limited. The order will be executed at their Wythenshawe, Manchester factory.

The models are intended for use with the unique Ferranti periscope simulation system also produced by E.D.E.D. This system presents a trainee operator with a periscope view which is a realistic representation of the view he would obtain in normal service. The ships are presented on a realistic sea-scape and the system provides variation in range, angle on the bow, water line elevation and speed under computer control. Completely authentic obscuration of targets by other targets is provided.

The present order calls for models of the various ships, both surface and underwater types, currently in use with the Navies of both Allied and other nations. The scale models reproduce key dimensions to an accuracy of 1% and include an indication of the bow-wave position. Each set consists of two models, at different scales, of a particular ship. These are mounted on a plinth enabling either model to be moved into the field of view of the camera providing the periscope picture.

Guide lines for diesel engine preventive maintenance

Almost all diesel engines can be regarded as essential, whether they are installed for ship propulsion, auxiliary power generation, emergency standby, industrial duty ashore or land transportation. The fact that they are so vital means that preventive maintenance is especially important.

Whilst most marine engineers have their own stores of knowledge based on personal experience they are or should be, willing to have the benefit of the experiences of others who use diesel power. A source of such knowledge is produced annually by the Diesel Engineers and Users Association in respect of industrial diesels, many of which are closely akin to modern medium-speed power units installed in vessels of various kinds.

The document concerned is the Working Cost and Operational Report, discussed each December. The part of that work to which we refer especially is "Analysis of Stoppages"; this was initiated six years ago by the Editor of our associated journal "Gas and Oil Power" and prepared by him for the six editions of the Report since then. Some 1,625 stoppages have been analysed and the two major causes of power break have been leakages of fuel, lubricant, water and gas (21.9%) and fuel-injection equipment (15.2%). The faults relate solely to actual stoppages and do not include those discovered during maintenance routines.

The following are the causes expressed as a percentage of the 410 events recorded in the most recently covered period of 12 months; consequential damage is not included as the object is to try to indicate the frequency of originating troubles.

Class of Defect	*Percentage*
Fuel-injection equipment and fuel supply	27.0
Water leakages	17.3
Valves and seatings	11.9
Bearings	7.0
Piston assemblies	6.6
Oil leakages and lubrication systems	5.2
Turbochargers (excluding damage by intruding foreign bodies)	4.4
Gearing and drives	3.9
Governor gear	3.9
Fuel leakages	3.5
Gas leakages	3.2
Breakages and fractures, other than under other specific headings	2.5
Miscellaneous	2.5
Foundations	0.9
Crankshafts	0.2
	100.0

It will be noted that the four forms of leakage account for a total of 29.2% of stoppages.

A feature of the six "Analyses" has been the relatively large number of identical failures in some plants containing groups of similar diesel engines. Such a case started with several broken fuel-injection pipes; these were replaced, but no precautions were taken with the pipes on other engines. Batches of them failed later. Had the first event been regarded as a warning a number of costly outages could have been avoided.

Possibly fatigue affected pipes which were inadequately supported by clipping to rigid components. During discussion of the 1970 Report it was suggested by some experienced diesel users that whilst fatigue manifests itself after varied numbers of running hours, it might also be connected with the number of hours elapsed since manufacturing machining. That seems to offer scope for a comprehensive research investigation.

Book review

Loss of the Scharnhorst by A. J. Watts. Published by Ian Allen, 90 pages, well illustrated. Price £1.25.

The sinking of the *Scharnhorst* in December 1943, although not realised at the time, was to be the last action of its kind fought by the Royal Navy. This is the story of that action. The book is divided into two distinct parts, the first giving a brief but comprehensive history of the naval war, supplies the necessary background for the understanding of the action. In the second part, twelve tables list the composition of the various forces, the technical specifications of the warships involved, and the detail of the radar and armaments. The text is illustrated with plans of the action and over 50 photographs.

*Two-stage rotary diesels**

A Rolls-Royce development for military service

Ever since the introduction of the Wankel rotary-piston engine with spark ignition there has been a demand for a similar design working on the compression ignition system. Objectives are the reduction of fuel consumption, multi-fuel capability (primarily a military requirement), small bulk and weight, the attainment of simplicity and the avoidance of those thermodynamic and metallurgical limitations which affect gas turbines.

Britain's Ministry of Defence placed a contract with Rolls-Royce Ltd for the developmenet of diesel and multi-fuel versions. A resulting advanced prototype is now running, after some six years' evolution work. It will be some years before routine military models are available, and commercial engines still

**Gas & Oil Power, March/April 1971*

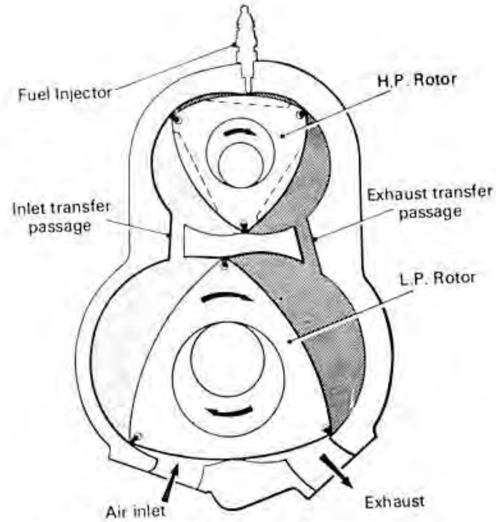


Fig 1. Two-stage design with two rotors

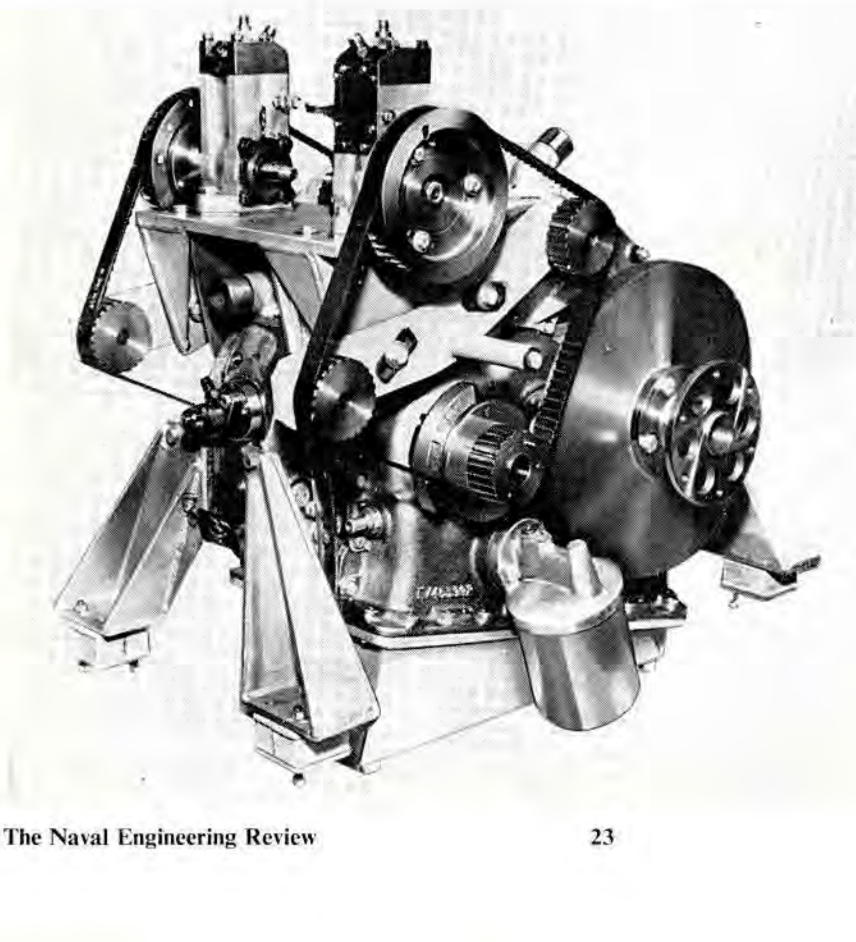


Fig 2. The R1 development

later. The Rolls-Royce Motor Car Division points out that such power units are not prospects for cars.

A report on this programme has been presented by Mr F. Feller, BSc(Eng), CEng, MIMechE, manager, Research Rotary Engines, Rolls-Royce Ltd, Crewe, in a paper to The Institute of Mechanical Engineers, entitled "The two-stage Rotary Engine—a New Concept in Diesel Power".

As a single-stage compression-ignition unit the Wankel did not seem very promising, for the following reasons: 1, difficulty of obtaining a high enough compression ratio; 2, a high surface/volume ratio at "top dead centre"; 3, a shallow and elongated combustion space; 4, an unconventional gas sealing system including single elements with only line contact.

Study of the problems suggested that raising the compression ratio could be attained by use of a Roots blower, or of a turbocharger, or of a positive displacement unit which would preferably increase the expansion ratio by the same amount as the compression ratio. Ideally it would extract energy from a second or after-expansion stage, supply energy to a first or pre-compression stage, and return the surplus to the output shaft. The third option (Fig. 1) was the most attractive and development was carried out (R1 type). Subjects covered were direct or indirect injection, diesel combustion—which is very different from that obtaining in reciprocating piston engines, injector positioning and sealing—one of the major problems as many have discovered (Fig. 2).

After a two-rotor design (R2 in Fig. 3) had been tried out and evaluated a three-rotor type (R3 in Fig. 4) was built up; this was planned to form the basic module of a future range of military engines up to 1,000bhp.

To date R3 engines have recorded 180bhp and 0.41 lb/bhp/h at 4,500 rev/min and 30 to 1 air/fuel ratio. The specific fuel consumption curve is fairly flat with the lowest reading of 0.39lb/bhp/h occurring at 3,500 rev/min. At an air-fuel ratio of 50 to 1 the minimum specific fuel consumption is 0.36 lb/bhp/h from 2,500 to 3,500 rev/min. All these figures are observed readings with the exhause unrestricted, but with the engine driving the injection pump, coolant pump and oil pump.

The RI form was originally designed to demonstrate the feasibility of the two-stage principle. By

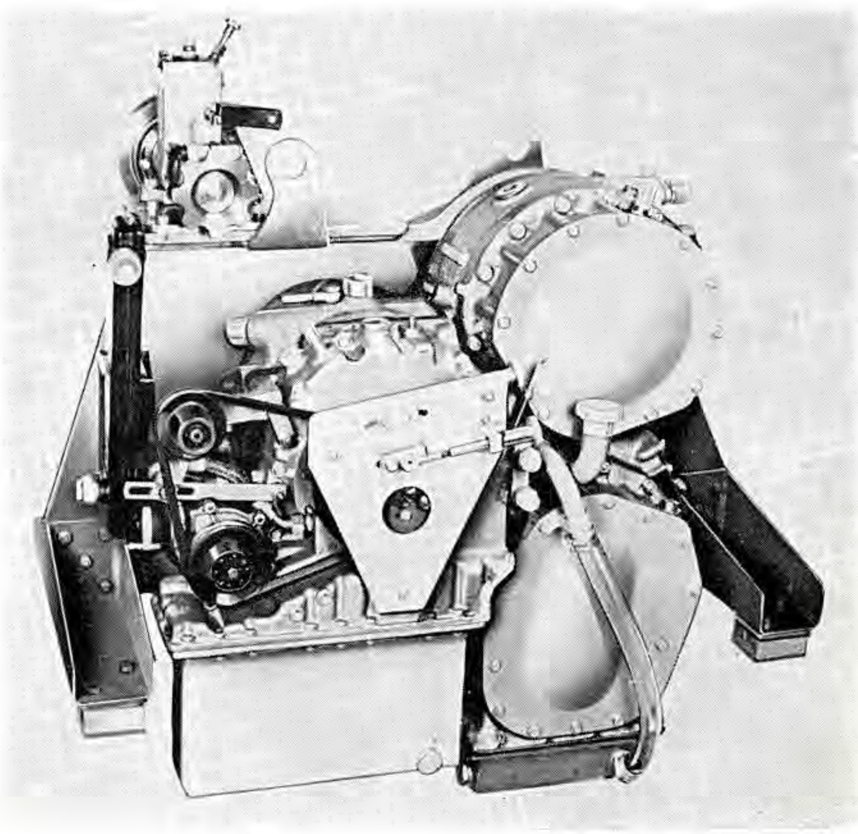


Fig 3. The R2 development

the beginning of 1969 it had been run for hundreds of hours and was nearing the end of its life as a research tool. New hardware was needed wherein could be incorporated the findings of the preceding four years. In consultation with the Military Vehicle Engineering Establishment it was decided to design a new and larger engine which, after a period of development, could be installed and run in a military vehicle. The engine would have two banks and was designated 2-R6. A single bank version 1-R6 would have sufficed to test all the essential components but would not have been suitable for vehicle applications.

It was requested by MVEE that the 2-R6 design should be made strong enough so that, by the addition of further banks, future power requirements up to 1,000 bhp could be met. Arrangements were requested also to test those features which are necessary to enable an engine having more than two banks to be assembled. Further, special attention was given in the design to such military requirements as wading and operation at large angles of tilt, also to the need quickly to clear oil from a full engine when being started after a long period of standing.

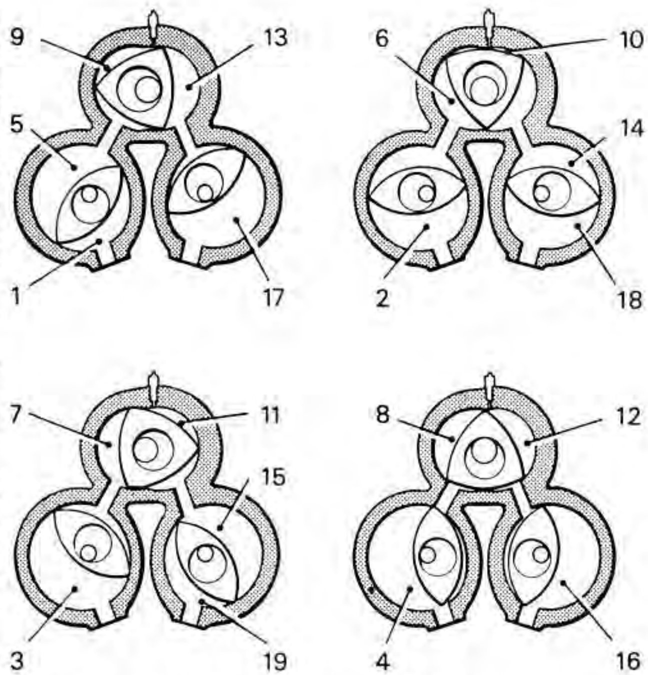


Fig 4. Two-stage design involving three rotors

2-R6 Engine data

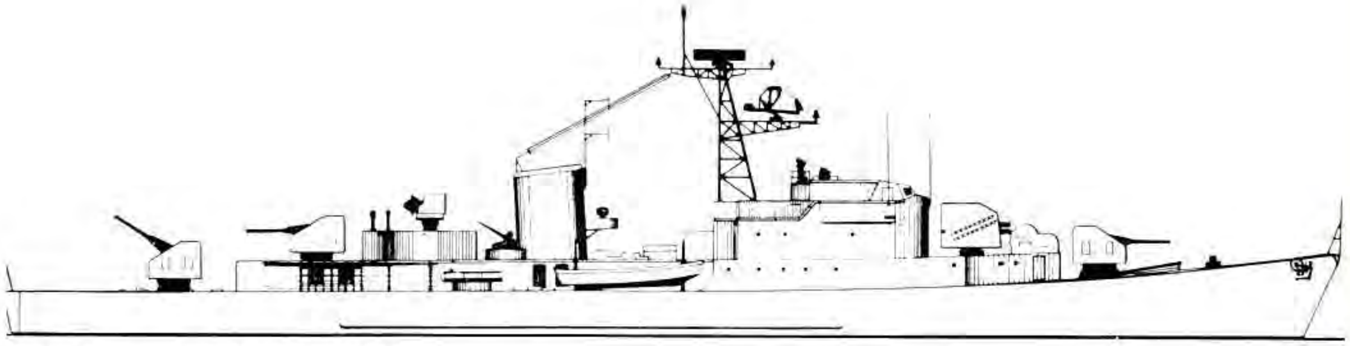
Number of banks	Two
Swept volume per bank:	1,265cm³ (77.2in³.)
HP stage	3,250cm³ (198.2in³.)
LP stage	6,500cm³ (396.4in³.)
Engine displacement	350bph at 4,500 rev/min
Output	835mm (32.8in.)
Height	726mm (28.6in.)
Width	718mm (28.2in.)
Length	0.435m³ (15.3ft³)
Bulk volume	450kg (929lb)
Weight (estimated)	

The 2-R6 has confirmed the overall size advantage which was expected from the rotary piston diesel.

Looking ahead

Work done so far has demonstrated the advantages of a compression-ignition type Wankel engine; these are: 1, high power/bulk ratio; 2, high power/weight ratio; 3, fewer components; 4, smooth power output. Whilst much more remains to be done, size and performance can now be predicted.

There are indications that with further development of the combustion system, increases in performance and efficiency can be expected. Also there is no reason why the specific output could not be raised further by adding a turbocharger, as in present diesel practice.



Profile of one version of this class of ship

*French CODOG frigate "Balny"**

First application of the Hispano/Suiza SNECMA M38 gas turbine to ship propulsion is in combination with two SACM diesels

The *Commandant Rivière* class frigates of the French Navy have proved very satisfactory in service. Construction of this 1,750tdispl series began in 1960 and the last of nine was completed early in 1965. Four similar ships ordered for the Portugese Navy have been delivered quite recently. Seven of those for the Marine Nationale were powered by four 12-cylinder SEMP PCV engines totalling 16,200bhp and geared to twin screws giving a speed of 24.5 knots. Two of them, the *Balny* and the *Commandant Bory*, were fitted with Sigma G34 free-piston gas generators and expansion turbines.

The ships have the following principal particulars:

Length overall	103.0m	(338ft 0in.)
Length bp	98.0m	(321ft 6in.)
Maximum breadth	11.5m	(37ft 9½in.)
Draught to propeller tips	3.8m	(17ft 6in.)
Full load displacement		1,950 tons
Endurance at 15 knots		4,500 miles
Ship's company		15 officers
		46 petty officers
		153 ratings

**Marine Engineer and Naval Architect, April 1971*

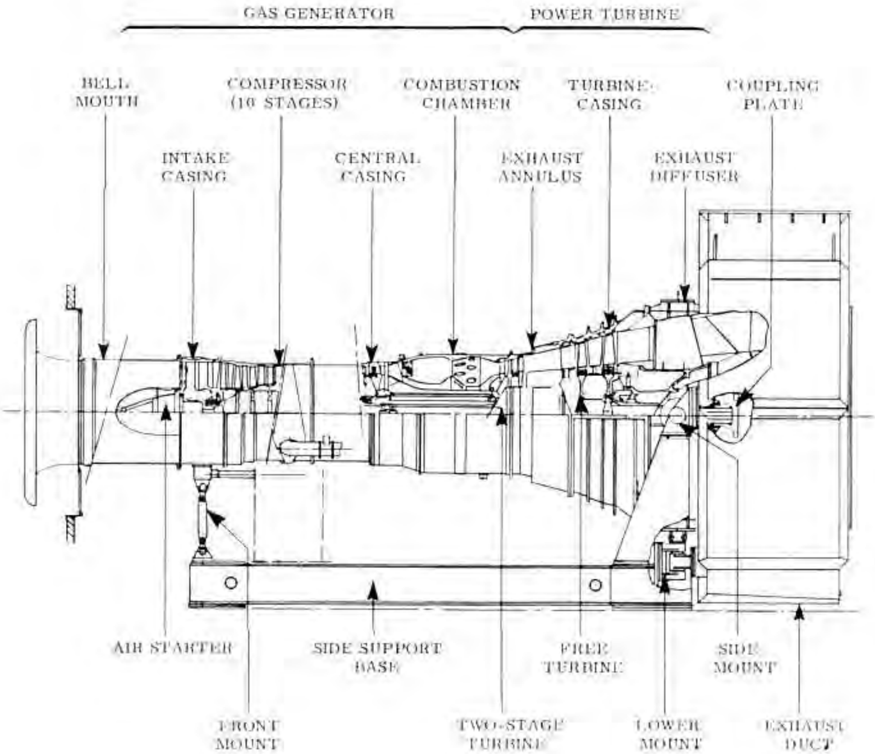
The armament consists of three (two in the *Balny*) 100mm automatic dual-purpose guns in single mountings, two 30mm Hispano-Suiza cannons, a quadruple 305mm AS mortar and two triple torpedo tubes.

Some time ago the French Navy decided to gain experience with aero-derived gas turbines and to replace the machinery of the *Balny* by a single-screw CODAG propulsion system, using well-established French prime movers.

Machinery

The machinery is installed in two compartments amidships: the gas turbine and primary reduction gearbox in the forward space, together with wing bunker tanks and auxiliaries, and the two diesel engines and the combining gearbox in the smaller after space.

The M38 Turboma/SNECMA (Société National d'Etudes et de Constructions de Moteurs d'Aviation) gas turbine which provides power is of two-shaft type with a maximum output of 12MW (16,000hp) at 5,000 rev/min at 15°C and 760mm Hg (sea level and 59°F). In this particular application, however, it is rated 14,700hp at 4,700 rev/min. It is based on the Atar aero jet and comprises a single-spool ten-stage axial compressor driven by a two-stage turbine

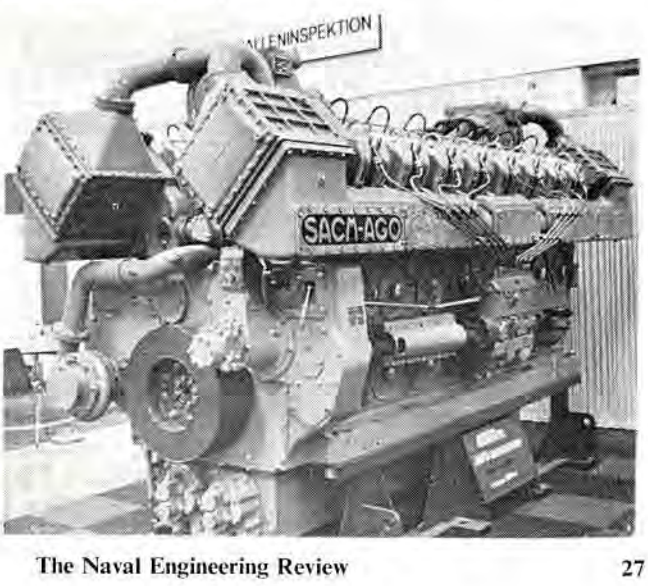


Left: Section through the M38 gas turbine showing restraint-free method of support

and a two-stage free power turbine.

The first stage compressor blades are of titanium and the remaining nine stages are of stainless steel, for resistance to corrosion by salt entrained with the air. The rotating assembly of the gas generator, comprising compressor and two-stage turbine, is carried in three bearings, a double thrust bearing at the front and roller bearings at the centre and rear. The stator blades are carried in a horizontally-jointed casing. An annular combustion chamber has 20 burner cans and two igniters.

SACM AGO engine of the type installed on either side of the low-speed shaft



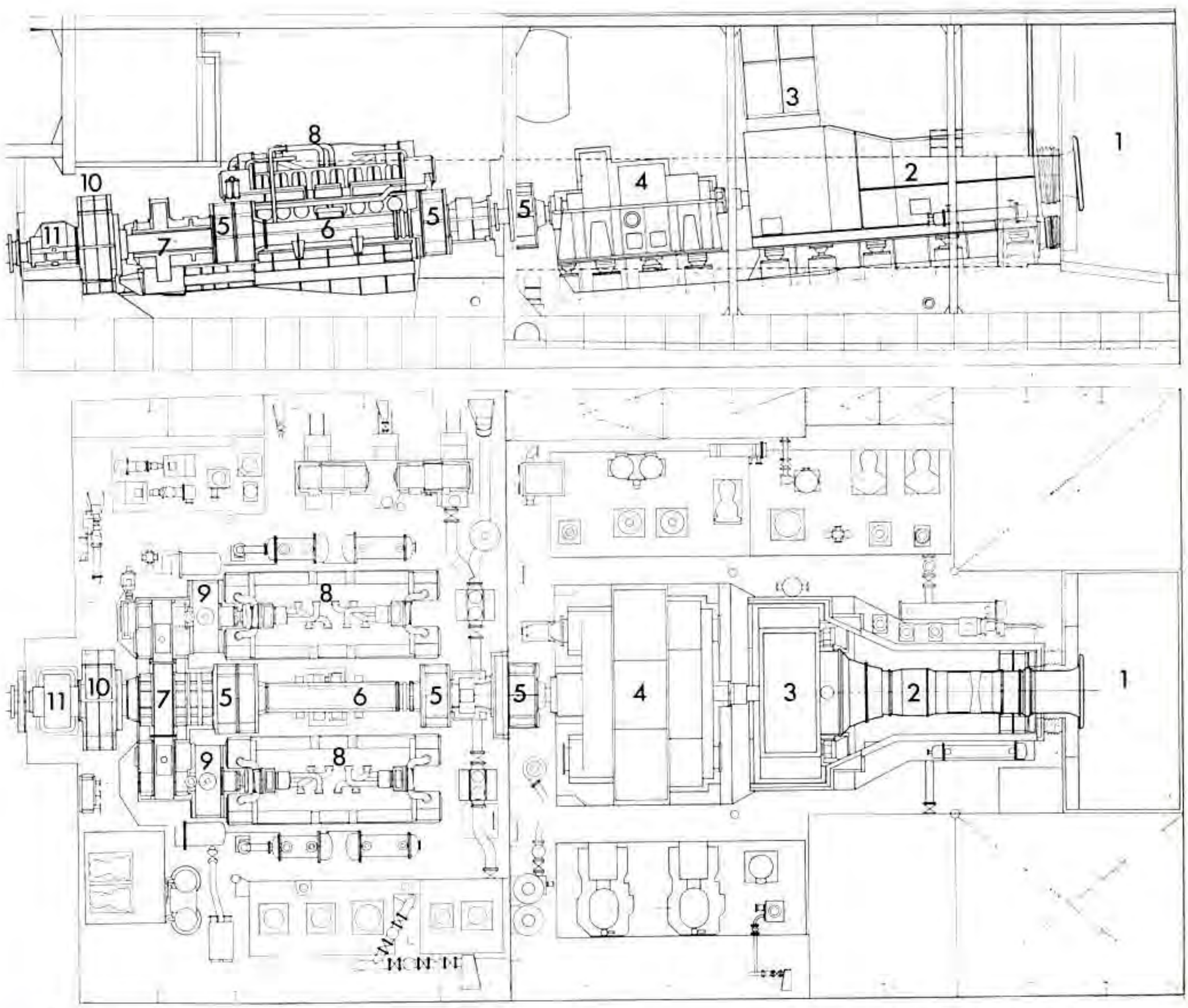
This gasifier is run up to speed by a compressed air motor, engaged axially and fitted within a pod at the inlet end of the compressor. The gas generator has a separate lubricating oil system using a synthetic lubricant, as is usual with areo-jet engines and an angle drive is provided for the auxiliaries.

The gases emerging from the generator then pass through the nozzle of the free turbine, the power turbine iself, the exhaust diffuser and thence to the uptake. The two-stage power turbine is overhung from two journal bearings, one of which absorbs the thrust. Here, again, the casing is split horizontally.

The compressor and power turbine sections are joined to form a single assembly which is supported by trunnions on brackets rising from the baseplate, with an additional location for absorbing torque at the bottom of the exhaust housing. Support at the

Arrangement of machinery in the ship. The transmission is unusual in that the turbine output enters the combining gearbox 7 at propeller shaft speed

1. Air intake plenum
2. SNECMA-Turboma M38 gas turbine (14,700hp at 4,700 rev/min)
3. Exhaust uptake trunk
4. Primary reduction gearbox
5. Flexible coupling
6. Cardan shaft
7. Three-input combining gear
8. SACM AGO 16-cylinder engines (1,800bhp each at 1,000 rev/min)
9. Engine input couplings
10. Output shaft coupling
11. Thrust block



inlet end is by pivoted struts which can accomodate expansion. The system of support is such that it is highly resistant to mechanical shock. The power turbine has a separate lubrication system using a standard grade of mineral oil and main and emergency pumps. Pumps and filter are integral with the turbine, the tanks and coolers are independent. The turbine is compact, being 5.6m (18ft 4in.) in length, 2.2m (7ft 3in.) in width and 2.9m (9ft 6in.) in height and has a weight, including foundation, baseplate and acoustic cladding of 5 tons (11,000lb). The exchangeable gas generator element is 4.5m long (14ft 9in.) and 1.5m (5ft) in diameter.

The turbine is enclosed by a sound-absorbent and air ventilated insulated casing. The output is taken from the turbine end through a clutch into a locked-train double-reduction gearbox and thence through a cardan shaft, with flexible couplings at each end, to the forward end of the low-speed shaft of the twin-input diesel reduction gear.

On each side of the cardan shaft in the after machinery space is an SACM AGO engine (Vee-16: 230mm x 230/220mm) of 1,800bhp at about 1,100 rev/min. Each of these engines drives through a freewheel clutch into the pinion of the secondary gearbox. This is a CODAG arrangement enabling the vessel to use one or both of the diesel engines, independently or in conjunction with the gas turbine, the freewheel clutches enabling any prime mover to take over from another or to supplement it without interruption of the power train.

The propulsion control equipment has been supplied by Compagnie Centrale d'Etudes Industrielle (COCEI). This embraces a control console and the means of controlling the sequential starting cycle, together with alarm and shut-down devices.

H.M.S. Drake to be salvaged after fifty-four years on the ocean bed

An attempt will be made this summer to salvage the wreck of World War I cruiser HMS *Drake*, which sank off Rathlin Island more than 50 years ago. The wreck, lying in shallow water in Rathlin's Church Bay, has long been a hazard to shipping and through the years several vessels have grounded on her. Steps are now being taken for a full-scale operation to salvage the thousands of tons of steel which today has a high scrap metal value. The job is expected to take between 18 months and two years. The plan is to cut up the 14,600 ton battleship into sections of around 50 tons, which will then be hoisted aboard another ship by a huge floating crane specially designed for the work. It is anticipated that the chief method of salvage will involve a series of underwater explosions to break up the hull.

With previous careful inspection by divers to ensure that no old explosives are remaining aboard which might still prove dangerous. HMS *Drake* was commissioned in March, 1901, just three years after she had been laid down at Pembroke Dock. A four-funnelled ship, she was well equipped with the weapons of war, including a dozen powerful 12-pounder guns, and a complement of 900 men.

It was on the morning of Tuesday, October 2, 1917, that her last voyage came to a sudden and dramatic end—ironically enough, just a few hours after she had successfully completed a dangerous ecort mission from the Mediterranean. The merchant ships which she had guarded on that perilous journey had dispersed and were discharging their vital cargoes in the Clyde and Mersey.

As the *Drake* was steaming in the comparatively safe waters off the Mull of Kintyre the German U boat 79 carried out a torpedo attack resulting in one officer and 18 men being killed. HMS *Drake* remained afloat and was able to reach the shelter of Rathlin.

Captain Stephen Radcliffe and his crew were taken off by two other Navy ships and shortly afterwards the stricken cruiser sank in about ten fathoms of water.

Now, with her hull a mere ten feet below the surface, the ghost ship is sometimes visible from the surface when the weather and tides are right. Boatloads of trippers on their way to and from Rathlin are fascinated by the story as told by the local fishermen—it has become something of a tourist attraction.

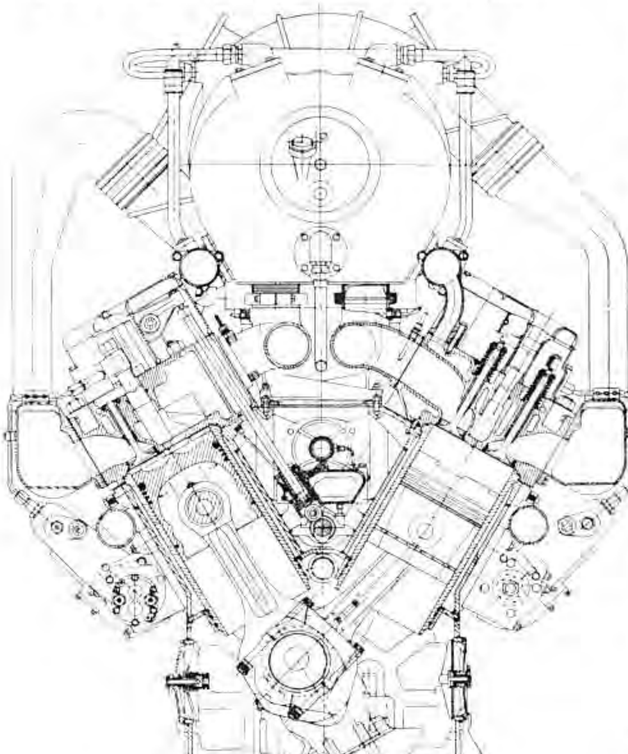
It is interesting to note that it was off the Giant's Causeway headlands, just a few miles from where the *Drake* lies, that another wreck, that of the Armada ship Girona, gave up some of her secrets. Two years ago a team of divers brough up a fascinating collection of priceless treasures from the seabed.

*Paxman-Ruston diesels in the service of the world's navies**

Since the first Paxman engine was installed in a naval vessel in 1933 well over 4,000 have been supplied to or ordered by 31 naval authorities. This figure does not include the more than 3,500 TP engines built for propelling landing craft during the war years. Paxman power for naval applications ranges from all-diesel propulsion equipment for fast patrol boats through numerous CODAG or COGOG combined power plant configurations for corvettes and frigates to a wide range of electrical power generation plants. The vessels concerned embrace the Royal Navy's latest and most powerful destroyers, gunboats, minesweepers, rescue and recovery craft, survey vessels, fleet auxiliaries and other support ships.

**Marine Engineer and Naval Architect, April 1971*

Cross section through the Paxman Ventura engine shows the ancestry of the Paxman Valenta engine



Current production of Paxman Vee-form pressure charged and intercooled diesel engines extends from the 7in. bore YH and RPH series built with from four to 12 cylinders and spanning a power range from 133 to 1,160bhp, to the highly popular YJ Ventura 7.75in. bore engine covering 750 to 2,400bhp (sprint rating) in six to 16-cylinder versions. Within this power bracket Paxman engines are incorporated as standard equipment in the Royal Navy and in many vessels for overseas navies built by Brooke Marine, Swan Hunter, Vickers Shipbuilders, Vosper Thornycroft, Yarrow Shipbuilders and other British yards.

The Paxman Ventura has emerged as the Royal Navy's Standard Range II engine, a worthy successor to the Paxman YH which held this distinction for some 15 years. Of some 600 Ventura engines installed or ordered during the last 12 years for industrial and marine applications some 400 are for naval use.

As prime mover for auxiliary duties the Ventura provides instant power availability together with reliability and economy, while in the propulsive role the last attribute considerably extends the range capability of a vessel either as the sole propulsion means or as the cruise engine of a CODAG or CODOG system. The current 16-cylinder Ventura engine has specific weights of 5.4lb/bhp (dry engine) or 7.4lb/bhp (engine and gearbox). These compare with figures of 8.6 and 13.0 respectively for one of the first 16-cylinder Paxman VRB engines built in 1960.

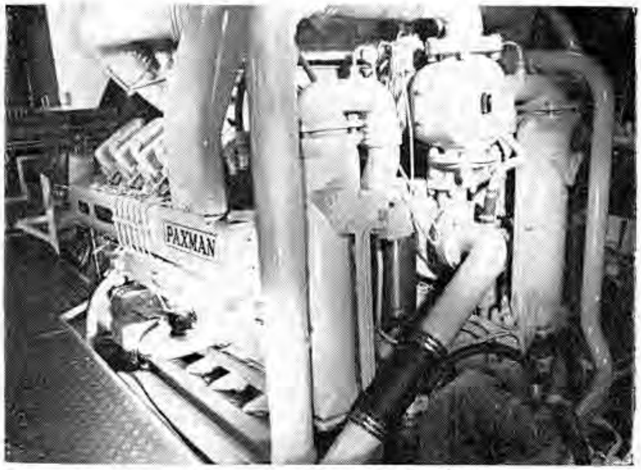
Recent orders and installations

Four Vosper Thornycroft-designed Mark 5 frigates for the Imperial Iranian Navy each have two 16-cylinder Ventura engines for the cruising mode of the CODOG propulsion system. The ships also have four six-cylinder Ventura ship's service generating sets installed in pairs in auxiliary machinery rooms forward and abaft the main engine room. These are discussed in greater detail elsewhere in this issue.

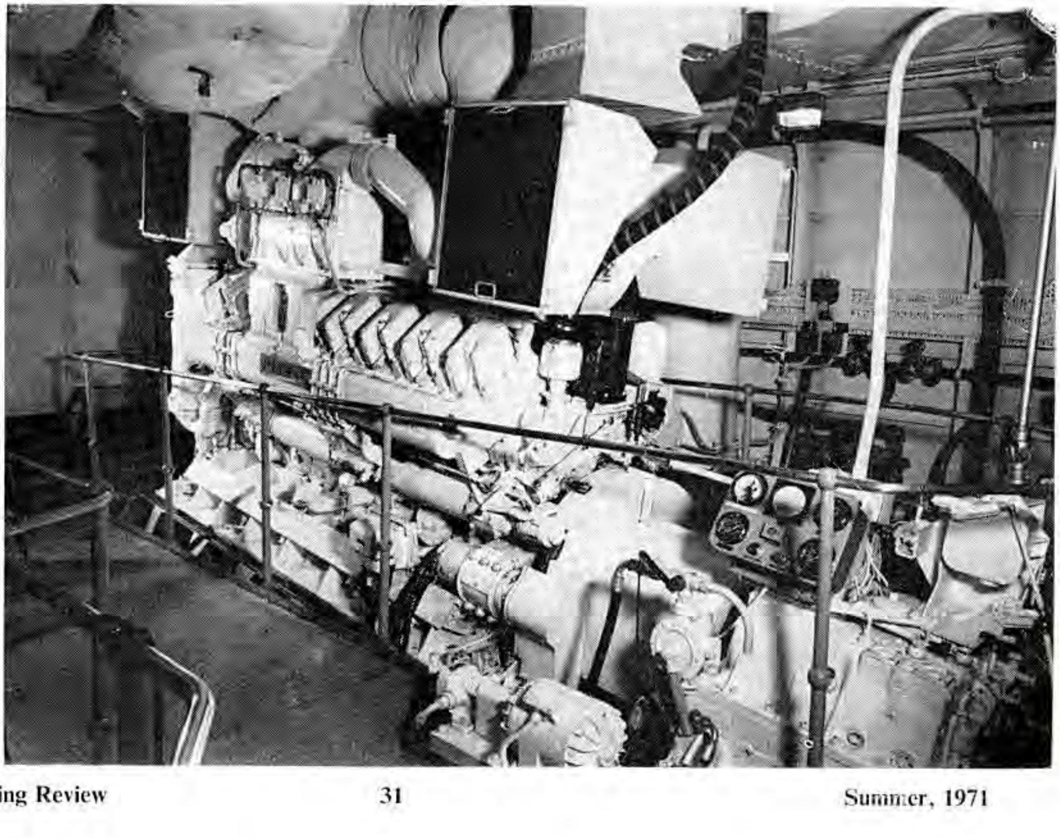
Typical of latest orders for Ventura-powered marine generating sets of 12 1,000kW sets, four per vessel and each incorporating a 16-cylinder Ventura drivng an AEI alternator. These will be installed in three Type 42 guided-missile destroyers for the Royal and Argentine Navies. Ventura powered generating sets of 750kW output are specified for the smaller Type 21 frigates building by Vosper Thornycroft and Yarrow for the Royal Navy.

The new Yarrow frigate for the Thailand Navy will have four 550kW Ventura-powered generating sets and two 550kW sets will be installed in each of the Chilean and Indian *Leander*-class frigates. The Royal Navy's guided-missile *County*-class destroyer *London* and the aircraft-carrier *Hermes* are to be retrofitted with 1,000kW Ventura-engined sets to carry additional electrical load.

Two 103ft fast patrol boats for the Panamanian Navy and two more for the Trinidad and Tobago coastguard are typical of a very popular design built by Vosper Thornycroft for Commonwealth and other navies. There are two 12YJCM Ventura propulsion engines developing a combined output of 3,600bhp in each. Brook Marine at Lowestoft are building three fast patrol boats of a new design for the Sultanate of Oman and each will be fitted with two 16YJCM Ventura engines developing a total of 4,800bhp. Among other vessels commissioned in



Forward end view of compact Ventura 12-cylinder engine. Two of these power Trinidad and Tobago coastguard patrol boats


Starboard hand unit of twin 16-cylinder Paxman Ventura rated 2,000bhp at 1,485 rev/min with reverse reduction gearbox as installed in long range support and recovery vessel

recent years with Paxman engines are the Vosper Thornycroft-built corvette *Tobruk* and the maintenance repair ship *Zeltin* for the Libyan Navy and three salvage tugs for the US Navy by Brooke Marine Ltd.

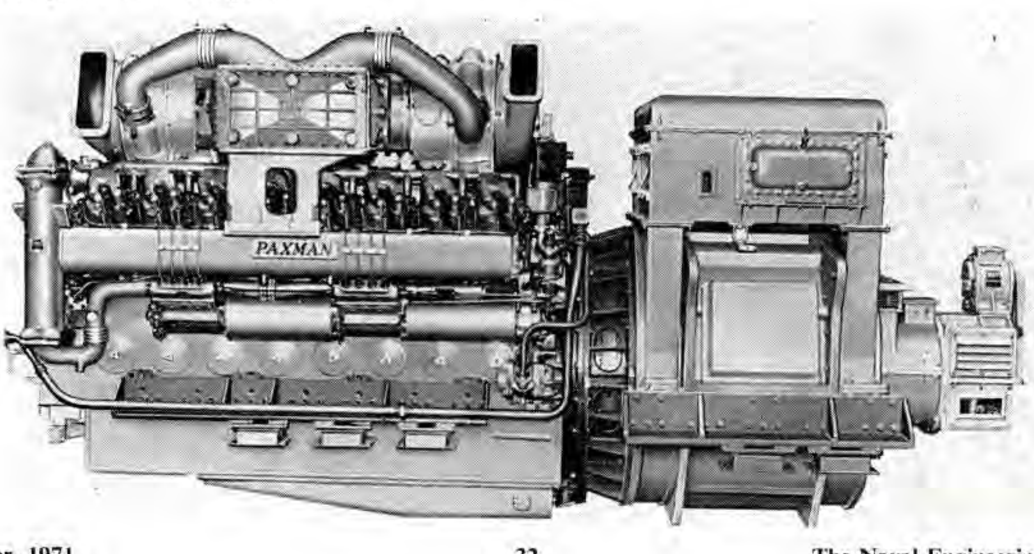
The proven ability of Paxman four-stroke Vee-form engines to meet the exacting duties and stringent specifications for naval application stems from basic design concepts that have identical successive Paxman design since production first commenced at Colchester in 1932. The crankcase/cylinder block is fabricated from high grade steel plate and carries hard chrome-plated wet-type liners and individual four-valve cylinder heads. Low weight has been achieved by the use of the latest metallurgical and fabrication techniques without sacrificing strength and rigidity. Fork and blade connecting rods link one-piece aluminium alloy oil-cooled pistons incorporating Alfin-bonded cast iron inserts, with a forged steel crankshaft carried in prefinished steel main bearing shells lined with bronze and lead-tin-flashed. A single camshaft in the centre of the Vee operates inlet and exhaust valves and the block-type fuel pumps mounted on each side of the crankcase are readily accessible. Close control of the tolerances and finish of all moving parts, together with precision balancing of the crankshaft and fly wheel, ensure vibration-free running over the full range of running speeds.

A well planned layout of the auxiliary equipment, such as the oil coolers and free-end drives, has kept these items within the overall engine envelope without detriment to access for maintenance. Ease of maintenance has always been a characteristic of Paxman Vee-form engine design and this is coupled with an ability to run for very long periods without major overhaul. Under good running conditions periods of 25,000 hours have been achieved. The maximum interchangeability of components is a Paxman-design precept and replacement spares can be fitted without any further work being done on them. This is of benefit to operators with many similar engines under their charge since a common spares stock can be held.

Valenta engine

The design philosophy which has proved successful in the existing range of Paxman engines has been carried forward into the Valenta, the latest and most powerful addition to the family. This new model has been introduced to meet the demand for yet greater specific output, without penalty of increased weight. The Valenta will be built with eight, 12 and 16 cylinders, covering a power range from 1,000 to 3,000bhp within the same envelope as the Ventura and with a specific weight of 5.8lb/bhp. An illustrated description appeared in the issue for February 1971. Twelve and 16-cylinder versions are currently being evaluated by the Ministry of Defence for naval service and it is confidently expected that this will take an important place in future naval powering. The first examples will, in fact, go into service with British Railways as the prime movers of the high-speed (125m/h) inter-city multiple-unit passenger train.

Standard Royal Navy 1,000kW auxiliary generating set powered by Paxman 16-cylinder Ventura engine.

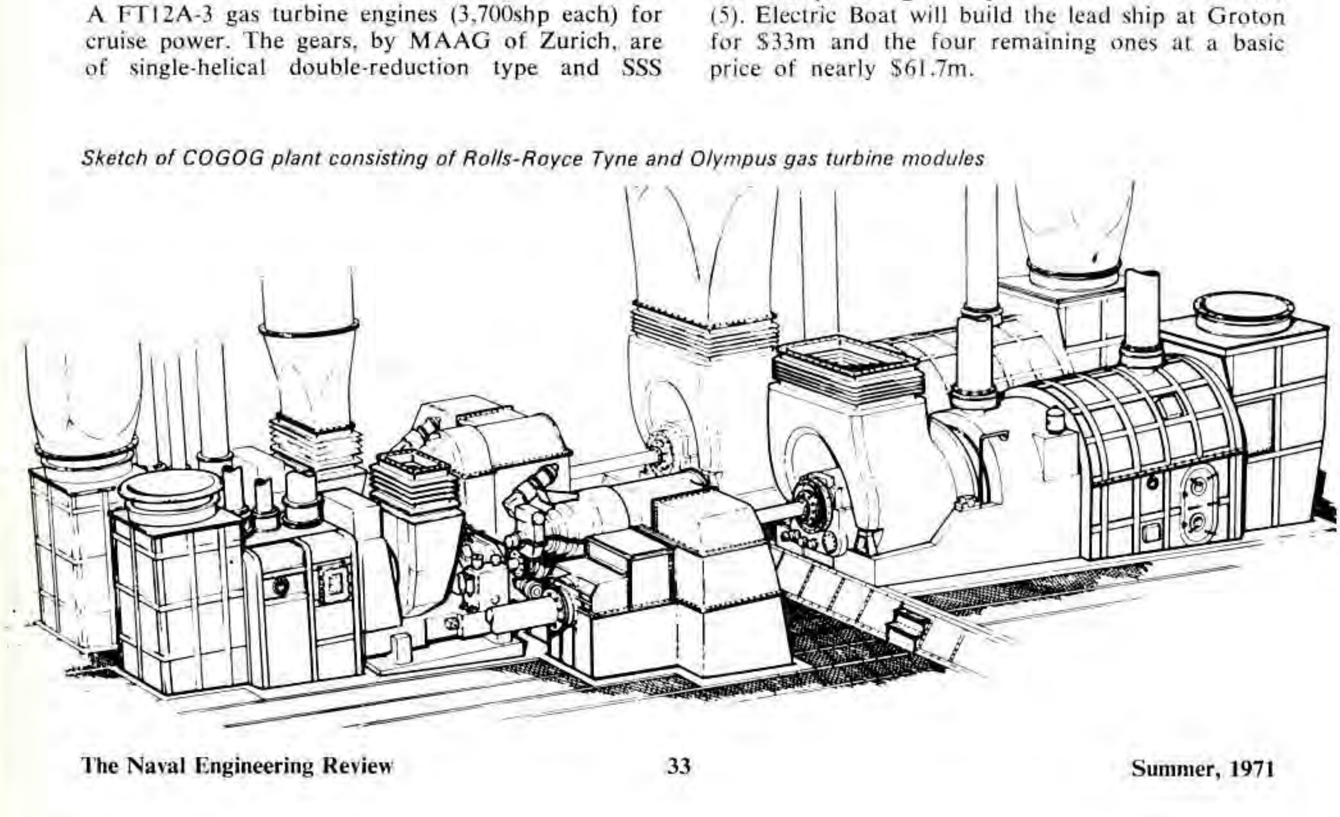


Did you know that . . . ?

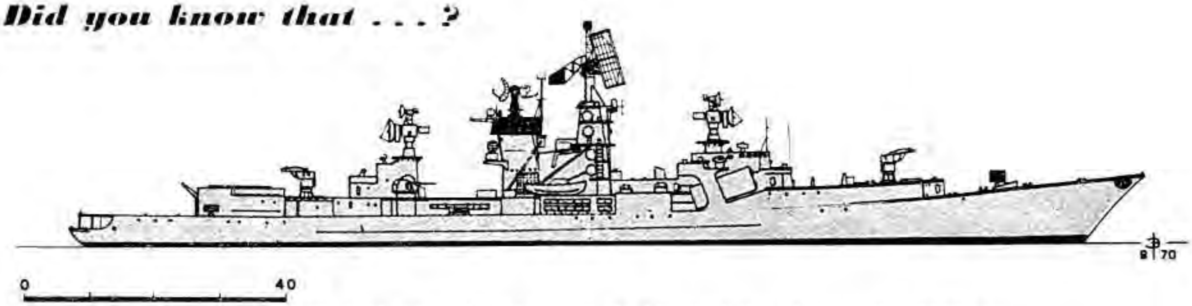
The first pair of gas turbine-powered destroyers for the Canadian armed forces, HMCS *Iroquois* from Marine Industries Ltd of Sorel and HMCS *Athabaskan* from Davie Shipbuilding of Lauzon, have been launched. These helicopter-carrying destroyers (DDH) will be the first of their size to use exclusively gas turbines rather than steam or COSAG plants for main propulsion. The major systems have been designed and developed in the Canadian Forces and Government Departments and by Canadian industries since the programme was announced in December 1964. The Industrial and Marine Division of United Aircraft of Canada Ltd is supplying the complete propulsion system and has been responsible for the extensive shore tests which were conducted last year at the United States Naval Ship Engineering Centre, Philadelphia. The gas turbine propulsion plant, to be controlled by a computerised command system, comprises two Pratt & Whitney aircraft FT4A-2 gas turbine engines (30,000shp each) for main or boost power; alternatively, two P & W A FT12A-3 gas turbine engines (3,700shp each) for cruise power. The gears, by MAAG of Zurich, are of single-helical double-reduction type and SSS clutches permit change of mode between cruise and boost or vice versa without interruption of the drive. The turbines and gearing are mounted on a raft which is flexibly supported from the ship's structure. For this reason flexible couplings are necessary in the main drive shafts. These are Vulkan highly-elastic rubber couplings, type EX560 and the thrust block is arranged further aft. The five-bladed Lips controllable-pitch propellers have been designed for minimum noise "signature". The turbines will be confined within sound and heat insulating casings contained under a slight vacuum by powerful exhaust fans in the case of the main turbines and exhaust eductors in the case of the cruise engines.

The United States Navy has ordered, at a cost of $760m, the first 12 Type 688 hunter-killer nuclear submarines from the Electric Boat Division of General Dynamics Corporation (7) and the Newport News Shipbuilding & Drydock Division of Tenneco (5). Electric Boat will build the lead ship at Groton for $33m and the four remaining ones at a basic price of nearly $61.7m.

Sketch of COGOG plant consisting of Rolls-Royce Tyne and Olympus gas turbine modules



Did you know that . . . ?



The new Russian g-m cruisers are flush-decked almost right aft. The deck line of the earlier 'Kresta's' is dropped at the end of the house

Sightings during the past year have indicated the existence of an entirely new class of large Russian guided-missile-carrying ship up to half a dozen of which are believed to be under construction at the Zndanov yard in Leningrad. Evidently of an improved and enlarged *Kresta*-class design, with standard/full load displacements of about 6,000/7,000 tons and, like that type, with the navigation bridge set some distance forward of the tower which supports what appears to be a 3-D radar scanner, there are two quadruple launchers for SS-N-3 surface-to-surface missiles in the wings of the bridge. Lack of very large intakes, exhausts suggests that steam propulsion is employed, with a probable 80,000shp on twin screws supplied by four boilers for a speed of about 33 knots.

H.M.S. *Antrim*, last of the eight county class guided missile destroyers to be accepted into service by the Royal Navy, was commissioned at Portsmouth on Tuesday (March 30). Armed with Seacat and Seaslug missiles, she is the third sea-going warship to bear her name, which in World War 2 was given to the RN trawler base in Belfast. The destroyer was launched at the Govan shipyard of Messrs. Fairfield Shipbuilding and Engineering Co Ltd in October, 1967.

In the context of the Government's policy of reducing force levels in South East Asia, and to streamline the administration of the Fleet, command of HM ships at sea is shortly to be centralised.

On May 1, 1971, the Commander-in-Chief Western Fleet, Admiral Sir William O'Brien, assumed full operational and administrative command of the Far East Fleet from his headuarters at Northwood, Middlesex.

The Commander Far East Fleet, Rear Admiral J. A. R. Troup, will be delegated operational command of the ships in his area until he hauls down his flag later this year.

The change means that for the first time in hundreds of years, there is one commander-in-chief for all sea-going warships.

A new era in the training of Royal Naval submarine crews was signalled by the recent opening of a computer-based Submarine Command Team Trainer (SCTT) at HMS Neptune, the R.N. training establishment. The SCTT system was developed jointly by the Ministry of Defence and the Electronic and Display Equipment Division of Ferranti Ltd. in Manchester, and is based on two Ferranti Argus computers.

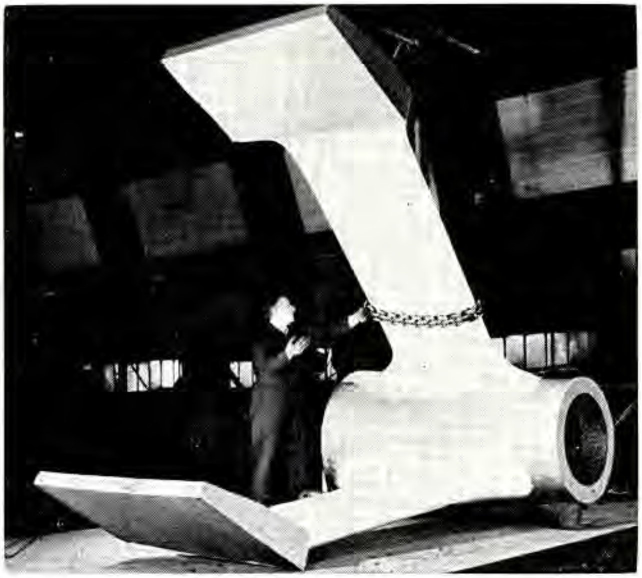
To mark the successful commissioning of the SCTT, a commemorative plaque was presented to Mr H. H. Thompson, Manager of Ferranti's Electronic and Display Equipment Division by Vice-Admiral J. C. Y. Roxburgh, C.B., C.B.E., D.S.O., D.S.C., Flag Officer (Submarines) at the Ministry of Defence.

The Non-Destructive Testing Centre at Harwell of the Department of Trade and Industry has collaborated with the Bristol Engine Division of Rolls Royce Ltd in what is believed to be the first successful use of high-energy X-radiography in the examination of the internal features of a running engine. They have perfected a technique using a Vickers Super X linear accelerator, for the inspection of running hot tolerances, in the Olympus 593 gas turbine engine.

The Penistone foundry of David Brown Gear Industries Ltd are supplying eight 12½ ton cast steel

Did you know that . . . ?

"A" brackets and eight smaller support castings weighing nearly two tons for the Type 21 frigate programme. The castings have support arms 9ft long and 5ft long propeller shaft housings and are ultrasonically tested. HMS *Amazon*, the first of the class, was launched by HRH Princess Anne at Southampton on April 26.

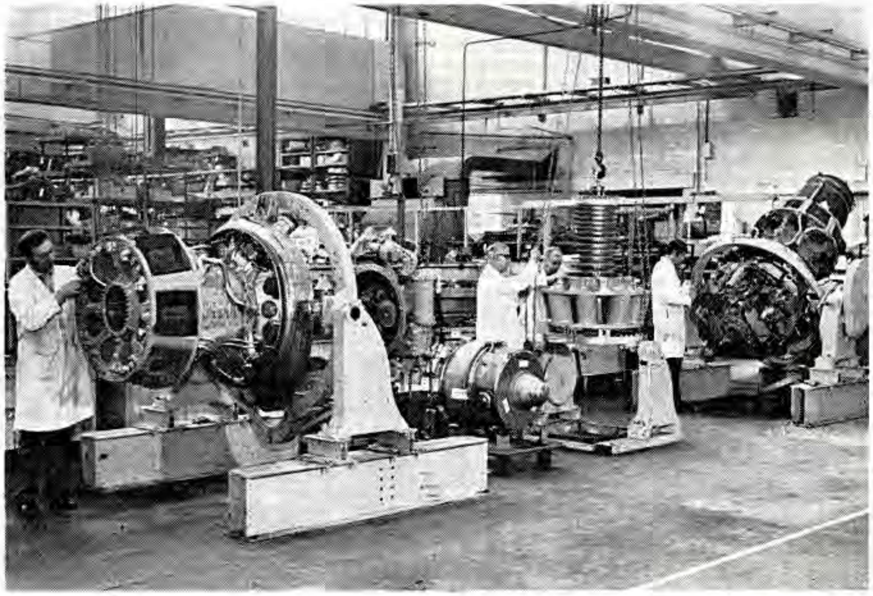


Cast steel A-bracket for Type 21 frigate

The Royal Belgian Navy has ordered four guided missile-carrying frigates, two from Boel's of Tamise and two from Cockerills' of Hoboken. They will be twin-screw ships in which each shaft will be powered by an Olympus gas turbine for maximum speed and a Cockerill CO240 Vee-type diesel engine for cruising.

The United States Navy is understood to have under development a class of small and fast destroyer with surface-to-surface guided missile major armament. This would, presumably, come between the present destroyer escort of the 2,650tdispl single-screw steam turbine-powered *Brooke*-class and the CODOG-powered *Asheville*-class patrol gunboats. These ships will be gas turbine-powered but with considerably greater endurance than the PGs.

Rolls-Royce (1971) Ltd have received an order for 16 Marine Proteus gas turbine engines for the Royal Danish Navy. An option has been taken for 12 more. The Royal Danish Navy has a squadron of six Proteus-engined (three per ship) *Brave*-class, fast patrol boats, the first of which were built by Vosper and the rest by the Royal Dockyard, Copenhagen. The latest engines are to be installed in a new class of fast patrol boat.



Marine Proteus gas turbines being assembled at the Rolls-Royce Industrial and Marine Division's factory at Ansty

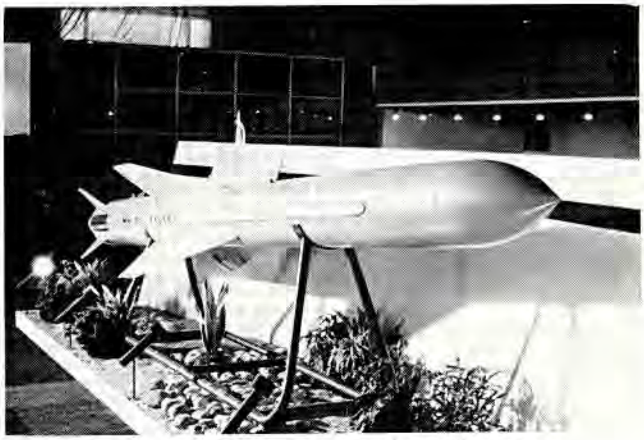
Did you know that . . . ?

In the Supplementary Statement on Defence Policy 1970 (Cmnd 4521) it was stated that subject to satisfactory conclusion of negotiations with the French government, it was intended that the EXOCET missile system should be widely fitted in surface ships of the Royal Navy during the 1970s.

After several months of negotiations, agreement has been reached on the terms of a contract for procurement of the EXOCET system and on a government to government Memorandum of Understanding, which will underwrite the contract terms. These, together, represent a satisfactory agreement to HMG. Decisions have therefore been taken to purchase EXOCET ship systems for wide fitting in frigates and larger ships, with a sufficient number of missiles to provide them with a surface to surface capability well into the 1980s.

On Saturday 5 June 1971 at the Air Show at Le Bourget an inter-Government Agreement relating to the EXOCET weapon system was signed by M Debre, Secretary of State for National Defence, said Mr Soames the British Ambassador in Paris. At the same time a contract for the supply of EXOCET missiles and associated equipment for the RN will be signed by the British Government and SNIAS, who develop the EXOCET system.

These agreements provide for participation by British industry in the series production of the system, and mark an important stage in Anglo-French co-operation in the armament field.



Exocet—the Flying Fish. French surface-skimming naval missile has a range of about 37 km (23 miles)

The 1,550 ton displacement destroyer escort *Ayase* was recently delivered to the Japan Defence Agency by the Tokyo Shipyard of IHI (Ishikawajima-Harima Heavy Industries Co Ltd). The dimensions are: 93.35 m in length, 10.8m in breadth and 7.0m in depth. The main propulsion machinery consists of four Mitsubishi UEV30/40N-type 12-cylinder diesel engines with a total output of 16,000bhp for a speed of 25 knots. ASCROC launcher.

On 21 May 1971 the Ministry of Defence announced that two *Sheffield*-class Type 42 destroyers have been ordered from Cammell Laird's, Birkenhead. These are the second and third ships of the class. The first ship of the class, *HMS Sheffield*, built by Vickers Ltd. at Barrow-in-Furness, was launched by the Queen on 10 June.

Machinery of the 'La Redoutable'

France has three 7,500/9,000tdispl nuclear-powered missile-armed submarines under construction at the Arsenale de Cherbourg and the prototype 'Le Redoutable' undergoing trials. These ships will be armed with sixteen ICBM missiles of Polaris type, but French design. Main propulsion machinery consists of a pressurised water reactor supplying steam to a pair of impulse steam turbines arranged in parallel and exhausting into separate condensers. The turbines are coupled through locked-train double-reduction gearing to drive a single propeller, an arrangement similar to that of the Royal Navy's nuclear submarines. Emergency propulsion is by a diesel-electric plant

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