Paper for written discussion

GAS TURBINES IN THE ROYAL NAVY, 1974 to 1976

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INTRODUCTION

The purpose of this paper is to provide an overall view of Royal Navy progress in the gas turbine field since the report made two years ago at the ASME Conference in Zürich (13). Thus it describes rapidly growing experience with the aero-derived Olympus and Tyne gas turbines in ships at sea, some of the technical problems encountered and their solutions, new engines under development and also research and development in various associated fields including that of intake air filtration.

SERVICE EXPERIENCE

Six Royal Navy ships are now operating at sea with the standard COGOG installation of Rolls-Royce Olympus TM3B and Tyne RM1A engines (Fig. 1)[6, 10, 16]. Since HMS *Amazon*

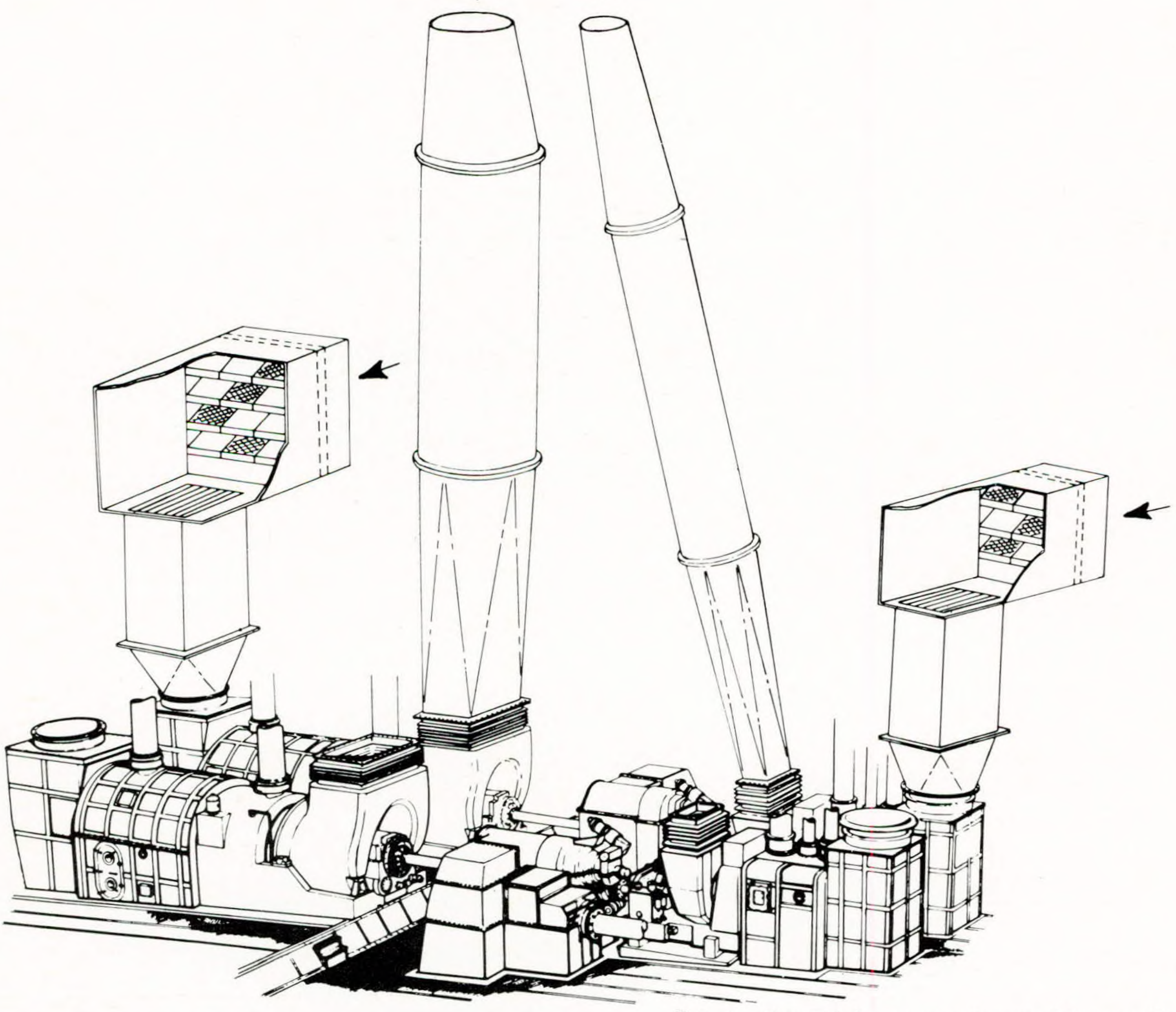

FIG. 1 —*Type 42 destroyer main propulsion machinery*

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*Procurement Executive, Ministry of Defence.

completed her sea trials in 1973, she has been followed by three other ships of this 3000 tonne Type 21 class: HMS *Antelope*, *Ambuscade* and *Arrow*. Of the larger Type 42 class (4500 tonne) HMS *Sheffield* is now in service and HMS *Birmingham* goes to sea very shortly. Some 11 000 hours of engine running have been achieved in many parts of the world including the arctic and the tropics. HMS *Sheffield*, for example, has gassed 11 000 nautical miles at an average speed of 14 kn and a fuel consumption of about 1·5 m/litre (100 ft/gal). Although effectively a prototype ship at first, she was never late on an expected time of arrival or departure: nor has she ever had to miss a scheduled exercise for engine room reasons. Experience with other ships has been similar.

Besides these British vessels, there are also the Netherlands Navy ships *Tromp* and *De Ruyter* and the Argentinian Type 42 Destroyer *Hercules*, all in service and using nearly identical Olympus/Tyne installations. The Olympus CODOG machinery in Brazilian, Iranian, Malaysian and Thai warships has been less heard of, but it appears to be running well. The French C70 corvettes with CODOG Olympus(2) are not yet at sea but the complete propulsion unit is now under test at INDRET near Nantes.

Meanwhile more engine running continues ashore. By far the most extensive is that of the Olympus in electrical power generation in Great Britain, USA and abroad, where 89 engines have now amassed more than 275 900 hours. Trial running of the Olympus and Tyne, sponsored by the Ministry of Defence, continues both at Rolls-Royce, Ansty, and the Naval Marine Wing of the National Gas Turbine Establishment at Pyestock, primarily to prove modifications before their introduction into general service (17). A different kind of shore trials running is that of the machinery for the *Invincible* class "anti-submarine cruiser" or CAH. Here one complete shaft set, comprising the gas turbines, together with main reduction gearing, fuel control systems and full scale replicas of the ship's intake and exhaust ducting, has been subject to violent manoeuvring trials to establish its behaviour under the most extreme transient conditions it can ever meet in service (11). The earlier mark of Olympus, the TM1A, is still giving good service in HMS *Exmouth* and *Bristol* and has achieved a total of about 13 000 hours running. The very much earlier G6 gas turbine, which first went to sea in 1961 in HMS *Ashanti*, continues to operate in the COSAG plants of eight destroyers and seven es and has built up a total of 93 000 hours.

TECHNICAL PROBLEMS IN SERVICE AND THEIR SOLUTION

As is only to be expected with new machinery of this complexity, there were some components that at first were not fully satisfactory. In no case did any of these difficulties prevent the engines running: their effect was generally to shorten component life. Solutions have been developed for all the major problems and are either already fitted in all engines or in process of being fitted (15).

OLYMPUS TM3B

Combustion

The combustion cans originally fitted in the Olympus suffered from two disadvantages. They produced visible smoke in the engine exhaust, which was undesirable for cosmetic and other reasons; in addition, distortion or cracking prevented their lasting for the full life of the engine.

Redesign of the burner shroud and combustion chamber flares has reduced the visible smoke considerably and an increased life will result from prevention of hot spots. Further alteration to air distribution and burner geometry should eliminate black smoke altogether throughout the power range. A further development of the combustion hardware, using rings *in lieu* of sheet metal spacers in the cooling air entries, offers still greater mechanical integrity.

LP Compressor Entry Guide Blades

Fatigue cracking was found in some of these entry guide blades, due to vibration excited by the rotor blade passing frequency. The solution has been to lean the entry guide blades forward so that most of the blade is further away from the rotor and the interaction is less.

LP Compressor Stator Blades

Two years ago(13) it was reported that corrosion induced fatigue cracks in the first stage LP compressor stator blades had been successfully overcome by shrouding that row. Unfortunately, further experience showed that although the original type of failure was prevented, cracking now occurred close to the blade tips due to the presence of the shroud. Several variations in the method of attaching the shroud to the blade were tried, without success, and it seemed for a while as if it was an intractable problem. In the meantime, however, engine trials with a very simple protective blade coating showed that this was itself successful in preventing the onset of corrosion. The blades (at present made of FV520 stainless steel) are shot-peened, vacublasted and coated with Rockhard lacquer; earlier fears that the lacquer would be worn thin and eroded prematurely have proved unfounded. Further improvement in life has been obtained by using a Sermetel W Coating, and in due course a more fundamental change will be made in new engines, in that the blade material will be Inco 718.

Fuel Control Valves

When the original aero Olympus engine was converted to a marine engine its fuel distributor, which originally divided and metered the fuel to the individual combustion chambers, was made to take on the additional role of converting fuel pressure into a unique value of fuel flow. This it did quite adequately except that it did not achieve precise repeatability of fuel flow, and this caused variations in idling speed between hot and cold engines, with consequent difficulties in setting up the controls and other problems.

The solution has been to fit a pressurizing valve instead of the distributor. The basic design of a piston moving linearly in a sleeve to meter fuel has been retained, the principle of using the pressure generated by the control system to position the piston being considered essential. However the force available for adjusting the piston position to correspond with a set change in pressure was increased and the inherent hysteresis of the valve assembly has been reduced by alterations in the detailed design.

TYNE RM1A

Combustion

In the early years of this engine its combustion chambers, like those of the Olympus, suffered from relatively short lives. The lips of the flares used to erode until the flare cooling air was no longer properly controlled and failure occurred. An interim improvement was obtained by changing the flare material to Stellite 31; and the present standard of can has a redesigned flare as well, featuring a double flare configuration for additional cooling.

The original combustion chambers also proved to be excellent manufacturers of carbon nodules on the burner head, swirler and flare. While there was little effect on engine performance, the carbon nodules contained a small proportion of very hard pyrolitic carbon which eroded the hot end components, especially the HP turbine blades but also the HP and LP nozzle guide vanes to some extent (14). This erosion did not cause any engine or blade failures but it did necessitate replacing all the HP turbine blades at overhaul. The problem may never be removed altogether but the new standard of combustion ware appears to overcome it adequately.

LP Compressor: Zero-stage Stators

Some cracking of the zero stage stators has occurred, especially following the use of anti-icing air. There is a proven solution to this problem, which consists of radial lacing wires at the ends of each segment of blading, reducing the maximum stress within the blade segment.

OTHER IMPROVEMENTS TO OLYMPUS AND TYNE RM1A

Current further development work on these two present-day engines has two objectives. Beside the obvious one of providing solutions to problems arising in service, it is also highly desirable to have a more general "component improvement programme" to benefit from modern technological advances as they occur. This programme aims to develop modifications not in response to particular problems but in order to increase the time between overhauls and so reduce through costs.

There must be a relationship between money spent on this type of work and the money saved as a result and it would be nice to know the break-even point. There would necessarily be so many uncertainties and assumptions in this, though, that the result could not be used with confidence and consequently it has not been attempted. In the absence of any such guidance on the optimum rate of such spending the actual constraints in the joint funding for this component improvement programme combined with that for solving problems encountered in service, are as follows:

> *Lower Limit:* The cost of maintaining an adequately strong engineering team; together with appropriate test bed running.
>
> *Upper Limit:* The relative importance and urgency of other calls on the funds available.

It must be remembered, too, that there is also a substantial read-across from work being carried out by the manufacturer on the industrial versions of the engines.

Work of this nature has been largely in the materials field, perhaps because that is one of the areas where gas turbine technology is advancing fastest. It is already planned to use Inco 718 in place of stainless steel for the stators and certain high temperature blade rows in the Olympus and Tyne compressors. Other materials are under investigation (see the Sub-section: Blade Materials and Coatings) but are not currently envisaged for these engines. Blade coating improvements are being pursued actively and rainbow sets are running in naval engines at NGTE Pyestock. Material changes in other engines have already given startling improvements in life. Thus a change from Nimonic 105 to Inco 738 in the HP turbine blades of the industrial Avon has resulted in a fourfold increase from around 3000 hours to 12 000 hours in the Middle East where both the intake air and the gaseous fuel contain high levels of sodium and sulphate. In the extreme conditions of civil hovercraft operation, Proteus engine life has increased from about 1000 hours to over 5000 hours as a direct result of material changes to X40, together with the use of better air intake filtration systems and stricter procedures for compressor washing.

The other approach to corrosion prevention, namely the use of additives in the fuel, is also being tried. An organic chromium compound, Nuosyn Chromium, has been found effective in laboratory rig tests and engine trials have so far shown no side effects.

TYNE RM1C

The Tyne RM1C or uprated Tyne, currently being developed, has 25 per cent more power than the RM1A under temperate conditions — 3982 kW (5340 bhp) instead of 3169 kW (4250 bhp) at 15°C air inlet temperature — and 38 per cent more power in the tropics — 3758 kW (5040 bhp) instead of 2729 kW (3660 bhp) at 30°C air inlet temperature. The essential difference between the two engines is a redesigned hot end with more blade cooling. The RM1A can be converted to the uprated version by incorporating a single large modification in the course of overhaul.

The RM1C is now well on its development programme and, with the exception of one group of problems, the programme is going smoothly. Full power has been achieved at the designed sfc and the only significant deviation from the brochure performance is the slightly lower LP compressor speed and the consequent marginally higher TET at full power due to a small mismatch of the power turbine. Blade metal temperatures, however, are as predicted so that the basic engine life has not been affected.

Over 1000 hours of development testing has been completed so far, including a 500 hour continuous endurance trial. A 2000 hour endurance run will begin at NGTE in the middle of 1976. The engine is due to enter service with the Royal Netherlands Navy in November 1976 and with the Royal Navy in March 1977.

The major problem area in the development of the engine has been erosion of the HP turbine blades by carbon, formed in the same way as in the RM1A. In the case of the RM1C however, the HP blades were at first very thin walled —0·0508 mm (0·020 in) at the leading edge — in order to achieve maximum cooling (Fig. 2) and the leading edges of some blades were dented by the impact of the larger carbon particles. In the longer term the solution lies in the reduction of the carbon forming, as already mentioned for the RM1A, but the blade design has also been changed to increase the thickness of the leading edge (Fig. 3). This has the effect of eliminating the impact problem altogether and extending the erosion life. As there was necessarily some delay before the new design of the blades could be delivered, the RM1C development engines were run on kerosene for their initial trials, thus temporarily avoiding the carbon problem altogether. At present one engine has the new blades and it has run successfully on gas oil for a 600 hour endurance run.

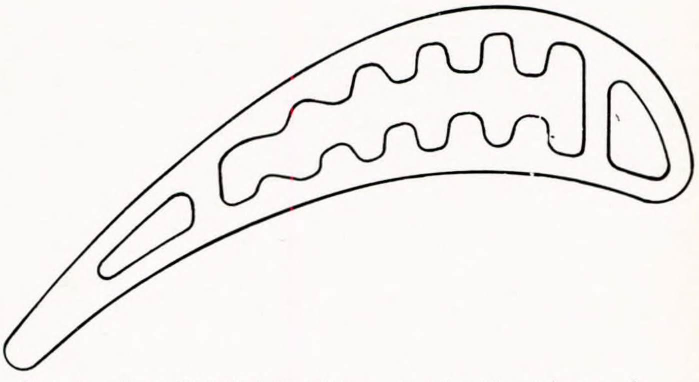

FIG. 2—*Tyne RM1C HP turbine — Section through an early blade showing thin leading edge*

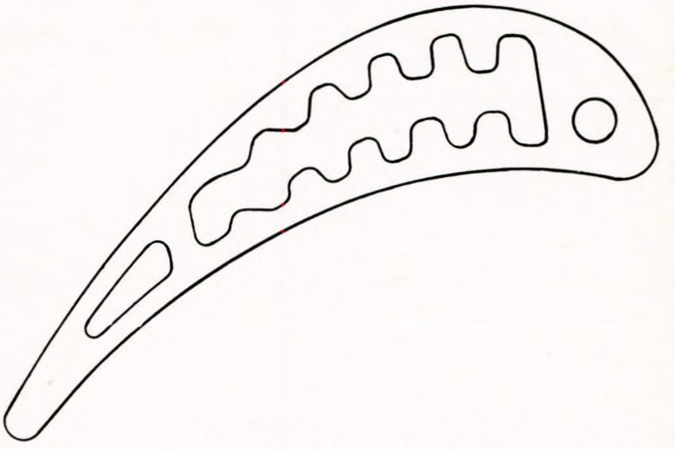

FIG. 3 —*Tyne RM1C HP turbine — Section through present blade showing strengthened leading edge*

In the early days of the RM1C development, high temperatures were recorded in the primary gearbox thrust bearing. This is a white metal bearing which was merely a plane disc for the RM1A. To take account of the higher speed and thrust of the RM1C shaft, eight taper lands were cut in the white metal of the plane disc, giving eight hydrodynamic wedges. This has run successfully on trial. A tilting pad bearing has also been designed and will be tried, which should be much more than adequate for the application.

Some tentative plans have been made for developing a light-weight highly rated version of the Tyne, the RM2D, for use in hovercraft or hydrofoils. The output would probably be about 4470 kW (6000 bhp).

SM1A

This engine is a marinized derivative of the Rolls-Royce/DDA TF41 aero engine which powers the Corsair aircraft of the US Navy and USAF. The TF41 is the most powerful variant of the Rolls-Royce Spey family and so benefits to some extent from the 13·5 million flying hours that this has done in civil and military aircraft.

The marine engine (Fig. 4) has a continuous rating of 11 000 kW (14 750 bhp) up to 86°F — 8948 kW (12 000 bhp) at 100°F — with an ability to produce up to 14 000 kW (18 770 bhp) for short periods. The sfc is 0·24332 kg/kWh (0·400 lb/hp h) at 11 000 kW (14 750 bhp) with good part-load fuel consumption.

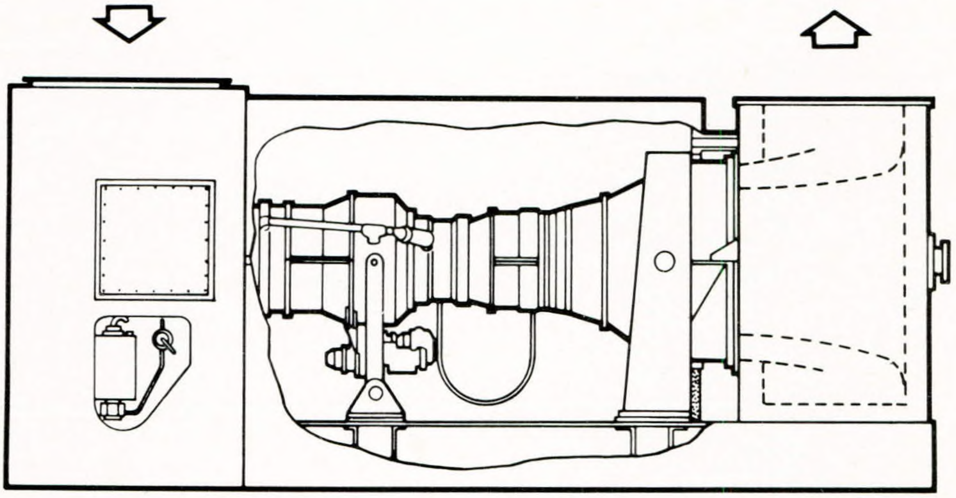

FIG. 4 —*SM1A — Sectional arrangement*

There are several ways of using this engine in warships of the future:

- a) a pair of such engines, COGAG, on each shaft of a frigate, thus combining a high full power capability with a very good efficiency at cruise speeds (when only one engine would be running), the extra reliability inherent in having two engines per shaft and the logistic advantages of having both engines the same;
- b) for higher shaft powers, the SM1A could be used as a cruise engine, COGAG, with a larger engine such as the Olympus or the FT9;
- c) in hydrofoils or large hovercraft.

Preliminary development of the SM1A started early in 1975. Rig testing in selected areas is now in hand as part of the project definition phase. Initial proving of the engine is planned to be followed by endurance testing both at Ansty and at NGTE Pyestock. An industrial version of this engine has also been built and run, which provides useful information for the marine engine.

In the early stages of development several interesting technical decisions have had to be made. They have been based on far wider criteria than those which sometimes govern design decisions, though all the factors concerned are part of engineering in the broad sense. These decisions, on such matters as LP compressor design, compressor blade materials, power turbine speed and number of stages, the use of electronic fuel control systems and the form of the air intake and exhaust volutes, have had to provide an optimum balance between the relative importance of some or all of the following parameters:

1) Specific fuel consumption;
2) engine size;
3) flexibility of performance in different roles (e.g. multi-engine installations);
4) predicted reliability in the marine environment;
5) degree of risk inherent in any change from the aero-engine design;
6) unit cost of production engines;
7) cost of overhaul;
8) cost of development.

A new design of LP compressor containing five stages is being developed in preference to cropping the original aero engine's bypass stages. It has been shown to provide very significant improvements in efficiency and part-load performance and also removes any necessity for LP bleed. The remainder of the gas generator is the same as in the TF41 except for material changes inherent in marinization.

The choice of two stages for the power turbine design is the outcome of extensive optimization studies and provides:

- i) minimum overall length and width of the installation;
- ii) satisfactory cyclic life;
- iii) minimum unit cost.

It also possesses sufficient performance flexibility to match with other engines in multi-unit arrangements.

ASSOCIATED GAS TURBINE RESEARCH AND DEVELOPMENT

Blade Materials and Coatings

The large amount of Ministry of Defence sponsored work in this vast field forms a subject of its own and cannot be more than mentioned here. It includes:

- a) investigations into the mechanism of hot corrosion;
- b) screening of new materials by corrosion and erosion tests, castability trials, thin section property trials, deposition trials etc;
- c) development of the ion-plating process;
- d) study of unidirectional solidification in corrosion-resistant materials;
- e) titanium alloy corrosion in the marine environment.

Some of the results of this work have been reported(3, 10, 12, 18). Further results were presented at the 3rd Conference on Gas Turbine Materials in the Marine Environment, held at Bath University (England) in September 1976.

Silencers

The full scale endurance trials of frigate uptake silencers(13) have continued and those for the through deck cruiser have been run concurrently(5). The Institute for Sound and Vibration Research at Southampton University has enabled the subject to be approached with something more than pure empiricism and NGTE's experience in silencing aero engines is being re-examined to determine its applicability to ship installations.

Engine Health Monitoring

This is being introduced into gas turbine ships on the lines explained at the last ASME conference(4).

INTAKE AIR FILTRATION

Salt Content of the Marine Atmosphere

It is clear that to know what effectiveness is required of a filter to enable it to produce an acceptable air purity at engine inlet, the expected salt content of the air outside should be known. Unfortunately this is complicated by many factors including height above sea level, humidity, recent history of the air mass and sea conditions and above all by the wind velocity. To obtain a meaningful set of data for atmospheric salt content a large sampling programme is necessary.

Some data were published as early as 1965 by Kaufman, who was able to supplement them two years later(9). His figures, in conjunction with some others, were then taken by NGTE and a table was produced(1) which has been used by

TABLE I — *Current standard marine aerosols*

Wind Velocity (knots) Particle size range in microns	20 %	20 ppm	30 %	30 ppm	40 %	40 ppm
<2	1·4	0·0038	0·1	0·0038	0·007	0·0038
2 to 4	4·6	0·0122	0·6	0·0212	0·07	0·0377
4 to 6	10·9	0·0286	3·9	0·1404	1·1	0·5585
6 to 8	13·8	0·0364	8·5	0·3060	3·8	1·9
8 to 10	13·8	0·0364	12·0	0·4320	7	3·5
10 to 13	15·8	0·0416	18	0·6480	16	8·0
13+	39·3	0·1040	56·9	2·0486	72	36·0
TOTAL	100	0·2630	100	3·6	100	50

them as a standard throughout all their testing since 1971. It is reproduced here as Table I and disregards any ship-generated spray. Its originators did not claim that it was necessarily right, only that it was the best summary of the then available evidence, erring if anything on the pessimistic (i.e. salty) side. Some of the data in Table I are shown graphically in Fig. 5.

Additional data are now available from a twelve-month sampling programme carried out at three ocean weather stations in the North Atlantic to the west of the British Isles (Fig. 6). The work was carried out by Lt. Cdr. R. F. Lovett as a M.Sc. project in association with Heriot-Watt University.

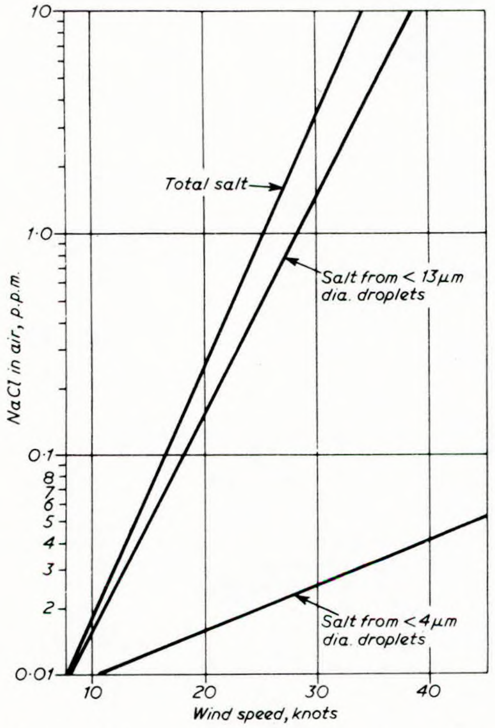

FIG. 5 —*Salt content of the marine atmosphere — NGTE standard figures*

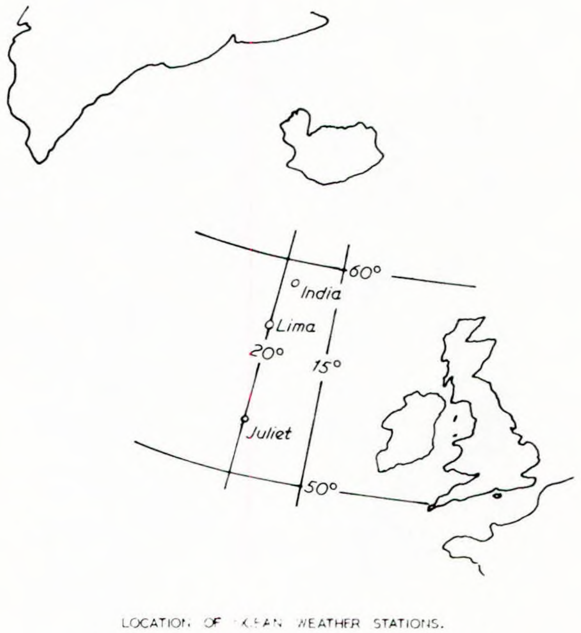

FIG. 6 — *North Atlantic atmospheric salt sampling trials — Locations*

Fig. 7 provides a summary of this new information, plotted in the same form as the NGTE data in Fig. 5. It will be seen that the N. Atlantic total salt concentration figures are much lower than those in the NGTE survey and that the gradient of the line drawn through them is less steep. The figures for salt in droplets up to 4 microns in diameter are also lower for much of the range, but the greater slope of Lovett's curve suggests that at higher wind speeds the effect of small droplets may be greater than was previously supposed. It is interesting that at wind speeds below about 15 kn (8 m/sec) no spray or aerosol salt is generated and that after about 12 hours at this condition the atmospheric salt content falls to very low levels, which must, therefore, be the norm in many parts of the world.

Despite the differences between Lovett's results and those of the NGTE compilation of previous data, the two are

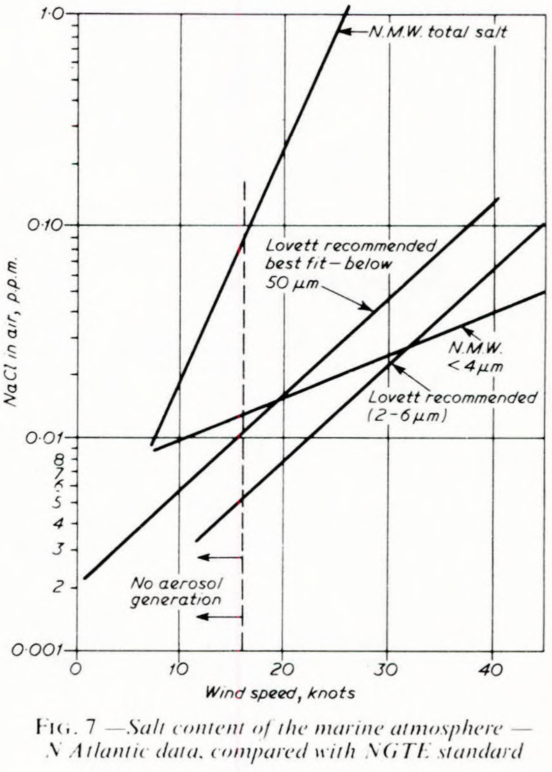

FIG. 7 —*Salt content of the marine atmosphere — N Atlantic data, compared with NGTE standard*

not in serious conflict. Certainly the deliberately pessimistic flavour of the earlier figures is borne out, but most clearly there emerges the need for more data. It will also be interesting to see a full analysis and interpretation of Lovett's material. Work shortly to be published(20) will also throw more light on the subject.

Demister Testing

The demisters currently being fitted to Royal Navy ships are of the three stage type(1, 13) in which a first stage inertial separator (to remove coarse spray and free water) is followed by a second stage of felted fibre which coalesces very small particles into droplets large enough to be stopped by the final inertial vane separator (Fig. 8). The American Navy view is that the first stage is unnecessary if the intake is in an adequately protected location(8). Neither navy is quite sure, the authors believe, and the Royal Navy is deliberately playing safe.

The present three-stage system was selected as a result of rig testing at NGTE and similar testing still continues so as to assess the performance of the various "improved" versions put forward by different manufacturers. The rig itself, together with the test procedures and methods of analysis, were developed by the Naval Marine Wing of NGTE. They have been described at length in a paper(1), based on unpublished work by Cutland and Boulton. The following account draws heavily upon it.

The rig (Fig. 9) has been designed so that air of controlled temperature and humidity, flowing at selected velocities can be exposed to variable amounts of water loading in which there is some limited measure of control over the input particle size. The salt concentration and particle size distribution can be measured both upstream and downstream of the filter being tested.

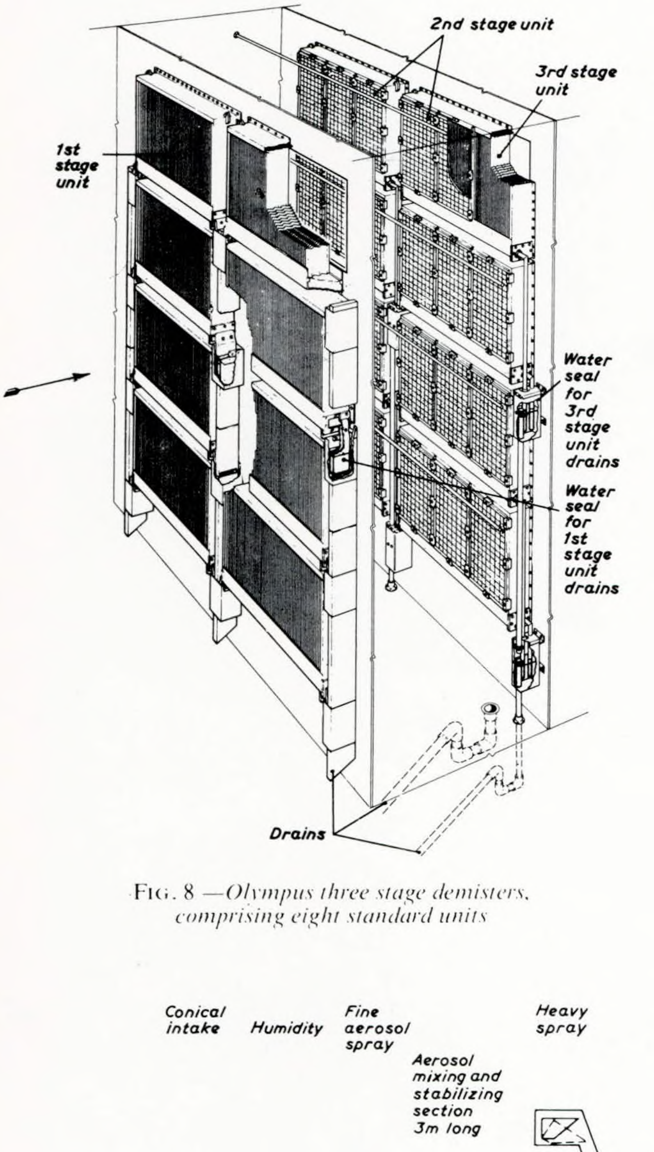

FIG. 8 —*Olympus three stage demisters, comprising eight standard units*

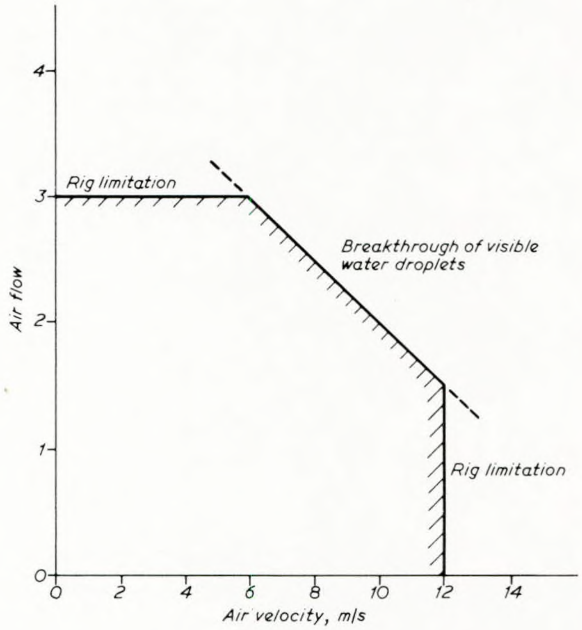

FIG. 10 —*Total water handling capability of a filter (air flow is measured in litres per sec per metre of drain trough length)*

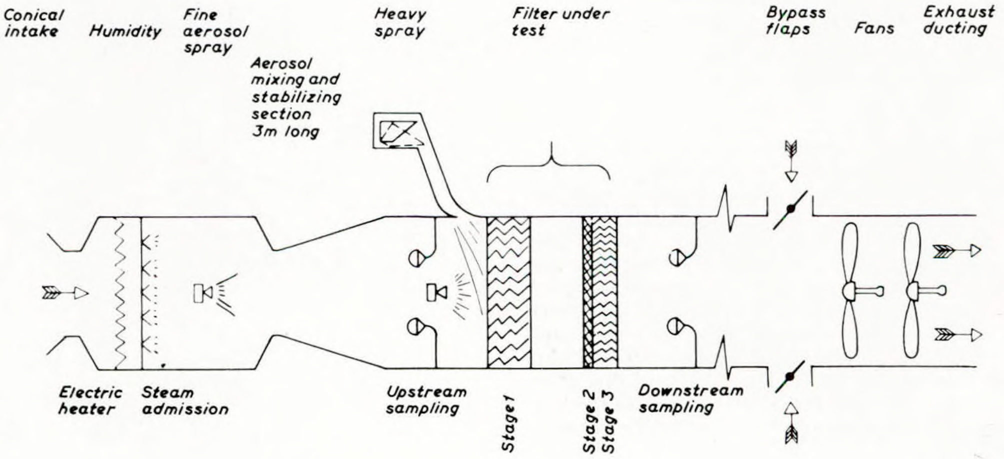

FIG. 9 —*NGTE air filter (demister) test rig*

Filters on test are routinely subjected to four different trials to measure:

1) pressure drop;
2) water handling ability;
3) filter effectiveness under coarse spray;
4) filter effectiveness under typical fine particle conditions.

The water handling tests serve to give a broad indication of the filter's ability to withstand the overloading by spray and water to which it may be exposed in heavy seas. No attempt is made to assess the filter's efficiency numerically under these conditions; the criterion is the point at which water breakthrough occurs sufficiently for visible spray to appear downstream of the filter. Each test of the series determines at what air velocity the breakthrough occurs for a given water loading. Fig. 10 shows a typical plot of results.

The tests of effectiveness under coarse spray are designed to measure the efficiency of the filter when exposed to a continuous water spray such as the "pre-wetting" used in warships to rinse away radioactive fall-out. The test is more precise than that for water handling capability but does not have all the refinements of the fine particle trial. Measurements at the sampling points downstream of the filter, using Casella Cascade Impactors and Millipore Filters, enable a plot to be made of salt concentration (ppm by weight in air) at each particle size band for a series of air velocities. Such a plot is shown in Fig. 11 for a typical filter. It is notable that the salt concentrations passing the filter under the very severe conditions, though far in excess of the statutory 0·01 ppm for normal conditions, are within one order of difference.

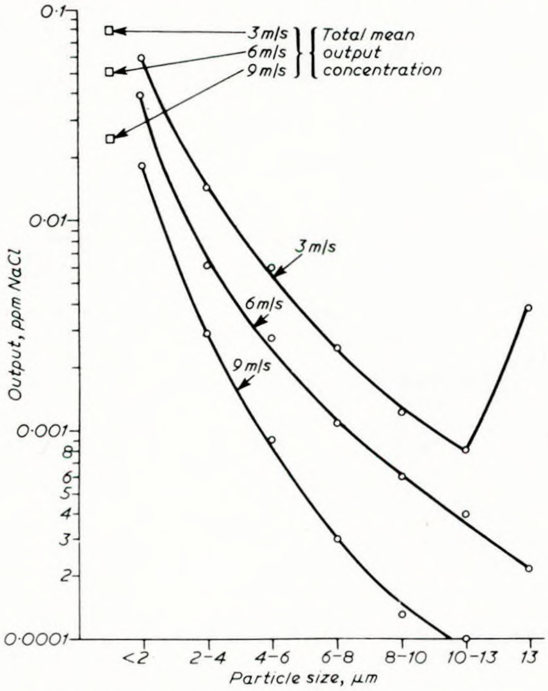

FIG. 11 —*Filter effectiveness under coarse spray*

The filter effectiveness under the conditions normally met with at sea, when all the atmospheric salt is in the form of relatively small particles, has probably the greatest influence on the life of the engine and it is for this reason that the methods used for assessing it are the most comprehensive. The salt droplets are introduced into the air stream solely from the aerosol spray atomizer. Salt concentration and particle size are measured both upstream and downstream of the filter. The total mass of salt collected by the millipore filter and the particle size distribution indicated by the stages of the impactor permit the cumulative percentage distribution by mass to be calculated. Plots such as that in Fig. 12 are then made for each air velocity. From these are derived the percentage contribution by each of seven particle size bands. These contributions, together with the total mean concentrations already obtained, give the concentration (in ppm) for each size band, both before and after the filter. From these the Penetration is calculated for each size band, Penetration (= 1 − efficiency) being defined as

$$\frac{\text{downstream concentration}}{\text{upstream concentration}}$$

By plotting the individual penetrations for each size band against input concentrations and then referring to the standard marine atmosphere content in Table I (or whatever may ultimately supersede it) it is possible to calculate the predicted quantity of salt (in ppm) that the filter would pass under the conditions expected at various wind speeds at sea (Fig. 13). By comparing these predictions with the acceptable limit of 0·01 ppm, the suitability of the filter for normal ship use can be assessed.

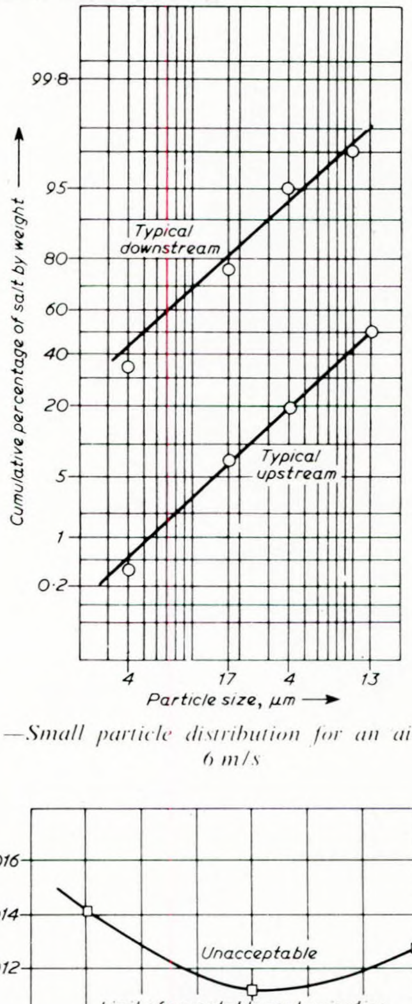

FIG. 12 —*Small particle distribution for an air velocity of 6 m/s*

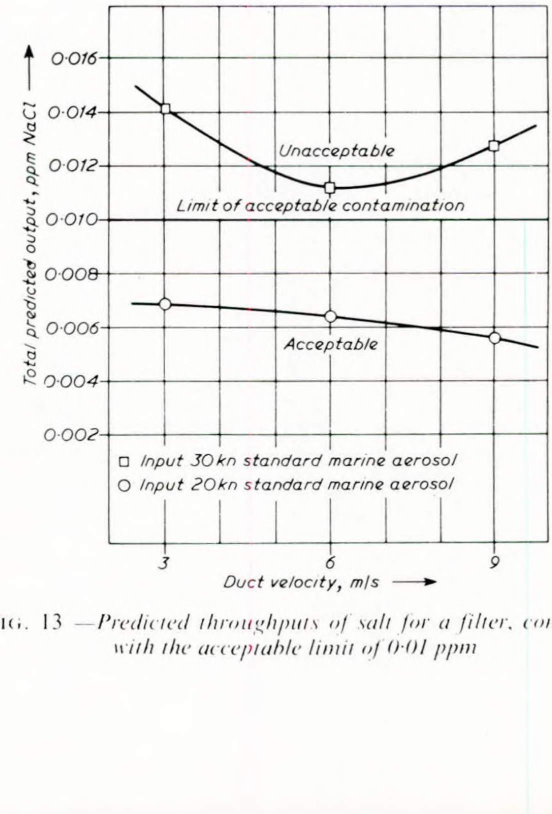

FIG. 13 —*Predicted throughputs of salt for a filter, compared with the acceptable limit of 0·01 ppm*

As all the filters tested at NGTE are of commercial origin it is not possible to divulge any of the actual results. Recent trials have been on some "compact" units in which the space previously considered necessary between the first and second stages is omitted, thus giving a smaller three stage system. Future work is planned to tackle the question of icing up, and also the problem of dry salt accumulation in filters under conditions of abnormally low humidity.

Sea Experience with Demisters

Building times for ships have been such that there as yet has been no experience at sea with the three stage demisters. It has, therefore, not been possible to compare the condition of engines in these installations with the earlier ones which were protected only by the less effective combination of an inertial first stage followed by polypropylene mesh, where salt deposits have occurred on the vanes of the intake cascade bend.

Compressor Washing Intervals

The presence of salt deposits in the compressors has two effects. Firstly, by affecting its aerodynamics it changes the engine performance and reduces its output: this is at least partly a temporary condition in that subsequent washing will restore most if not all of the lost power. Secondly, though, a heavy salt deposit will shed fragments which then pass further down the engine and impact on the hot surface of the turbine blades where they will initiate corrosion(14). Water washing can prevent the build-up of salt to detachable and hence damaging levels and the problem is to find the right compromise between too frequent washing, which interrupts the ship's operation unnecessarily, and not washing often enough, with a consequent permanent reduction in engine life and performance.

Trials are being undertaken to measure the salt concentration that compressors discharge, with different washing intervals, in order to:

i) further understand the mechanism of hot corrosion by salt;
ii) optimize the washing interval in service.

LOGISTIC SUPPORT

The logistic support of gas turbine warships is the subject of a separate paper(19). Perhaps the most interesting aspect, though not necessarily the most important, is the fact that the Olympus gas generators used by three European navies are now held in common ownership by all three and allocated impartially between all the ships concerned.

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