THE MANAGEMENT OF THE GAS TURBINE PROGRAMME FOR R.N. SHIPS

BY

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This article is an edited version of the opening address to a discussion group organized by the Manufacture and Management Group and held at the Institution of Mechanical Engineers on 26 November 1974. At that time Captain Melly was Deputy Director of Engineering (Marine) in the Ship Department.

Introduction

For the original opening address, the scene was set by a series of slides showing ships and gas turbines. These are not reproduced here because most of them have been seen in previous issues of this Journal. In particular, the reader is referred to:

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21	2	332
21	3	350
21	3	449
22	1	60

The Royal Navy is not alone in adopting gas turbines for propulsion, there now being quite an impressive list:

Russia	?	Libya	Olympus
Netherlands	Olympus/Tyne	Malaysia	Olympus
Belgium	Olympus	Thailand	Olympus
France	Olympus	Denmark	FT4
Argentine	Olympus/Tyne	Canada	FT4 and 12
Brazil	Olympus	U.S.A.	LM2500
Finland	Olympus	Italy	LM2500
Iran	Olympus		

Several other nations are in the process of adopting gas turbines of one make or another, but have not yet signed contracts.

Brief History

The Royal Navy's decision to move away from steam-turbine propulsion of major surface warships and to adopt in its place gas-turbine propulsion was based on the following considerations amongst others:

(*a*) No significant advance in steam technology appeared likely.

(*b*) The problems of boiler maintenance are overwhelming.

(*c*) The quality of life for marine engineering mechanics serving in steam ships is poor.

(*d*) The superior maintainability of gas turbines by using upkeep-by-exchange principles.

This decision which began in the Ship Department was approved by the Naval Projects Board and by the Defence Equipment Policy Committee and was finally endorsed by the Naval Engineering Committee (now the Machinery Committee); this latter is a high level industrial committee that comments upon broad policy matters which are discussed before it.

Arrangements were made to convert H.M.S. *Exmouth,* a *Blackwood* Class frigate with a 15,000 s.h.p. single-shaft steam plant, to be a trials ship (see *J.N.E.* Vol 16, No. 3, p.451). The steam plant was replaced by a COGOG gas-turbine plant comprising two Proteus and one Olympus TM1A gas turbines restricted due to shaft limitation to 15,000 s.h.p. The ship went to sea on 6 June 1968.

Typical examples of the development problems encountered in this trials ship were (see also *J.N.E.* Vol. 21, No. 1, p.137):

Olympus TM1A

(*a*) Fatigue failures of the compressor first-stage moving blades due to excitation caused by air-flow distortion with an unrestricted air intake: this was corrected by a cascaded bend in the intake.

(*b*) Heavy deposits of salt in the compressor: this was corrected by improved sealing around the edges of the air filter pads, and also by improved filtration to remove the bulk of the heavy spray.

(*c*) Clogging of air passages around the fuel burner tips after cleaning by carbo-blast resulting in burner extinction on rapid deceleration and failure to relight: this was corrected by a modification to the burner and by more regular water or solvent washing, and by restricting the use of carbo-blasting to infrequent occasions when liquid washing is shown to be ineffective, and when air inlet temperature is below 1°C.

(*d*) Excessive noise from unsilenced exhaust.

(*e*) The rapid choking of the original filters upstream of the coalescers and of the coalescers themselves: this was corrected by fitting additional duplex filters upstream of the coalescers.

Proteus

(*a*) The failure of the engine gearbox planet bearings under reverse torque conditions: this was corrected by modifying the oil feed arrangements.

The experience gained in H.M.S. *Exmouth* proved invaluable in the development programme, for the Olympus TM3B in particular and also for the Tyne RM1A. These two engines were being developed concurrently with the gaining of sea experience, and the development programme had a cost and time scale as follows:

Olympus TM3B	£
Y-ARD design study (Nov. 1967-Nov. 1970)	24,640
Engineering development (Apr. 1967-May 1971)	513,440
Module development (Oct. 1968-now)	1,373,350
Shock trials (June 1971)	18,000
Smoke reduction (Nov. 1969-now)	158,000
Approximate total	2,087,400

Tyne RM1A	£
Y-ARD design study (Dec 1967-Nov. 1970)	22,220
Engine development (June 1967-May 1972)	2,331,400
Module development (Jan. 1969-now)	1,282,400
Shock (Sept. 1971)	19,500
Approximate total	3,655,500

The Tyne RM1C is now being developed to produce more power than the 'A' version, and also to improve the overhaul life and reliability. When the engines become available, they will be fitted in place of the existing 'A' rating engines as they become due for repair or overhaul; these earlier engines will then be modified to the 'C' configuration and rating at the overhaul facility. Development started in July 1970 and up to November 1974 about £932,000 out of a budget of £1·6M had been spent.

Examples of typical problems encountered during the development of all these engines were as follows:

Olympus TM1A

(*a*) Fatigue failure of L.P. compressor blade after 1529 hours running.

(*b*) Vibration of the power turbine (near maximum operating speed) principally at shaft rotational frequency: this was cured by moving the tail-end bearing 10 inches towards the output coupling.

(*c*) Failure of power turbine rotor blade after 437 hours running: this was cured by cropping the blades and by using loose lacing wire.

(*d*) Cracking of the power turbine volute.

(*e*) Fatigue failure of H.P. turbine rotor blades which occurred either in the top serration of the fir-tree root or in the blade form near to the root: this was cured by stiffening the disc and modifying the blade.

Olympus TM3B

(*a*) Salt-water corrosion fatigue of the compressor first-stage blades: this was corrected by water washing; spraying with WD40; applying Rock-hard lacquer after manufacture; changing the blade material to titanium alloy; and by shrouding the first-row stator blades. Subsequently the blade material was changed to Inco 718.

(*b*) Cracking of the white metal surfaces of the power turbine thrust bearings and high temperatures of the pads: this was cured by using direct spray lubrication and offset pivot pads.

(*c*) High temperatures in the acoustic enclosure: this was corrected by fitting a radiation shield around the engine and by increasing the air supply. Future action will be ventilation by volute (see *J.N.E.* Vol. 21, No. 3, p.356).

Tyne engines

(*a*) Power turbine rotor blade failure.

(*b*) Excessive bearing temperature in the primary gearbox.

(*c*) High-speed torque tube vibration.

(*d*) High temperatures in the acoustic enclosure.

(*e*) Distortion of the rubber mounts.

(*f*) Build-up of carbon on the burners.

(*g*) Corrosion and burning of the combustion flare.

Management Control

Control of the work at Rolls-Royce was exercised through two bodies as follows:

Contract Control Team

This team comprised:

(*a*) The Project Leader (Head of the gas turbine section of the Ship Department).

(*b*) The Project Officer on the staff of the Project Leader.

(*c*) A representative of Naval Contracts.

(*d*) A representative of Naval Accounts.

(*e*) A representative of Naval Production (technical costing).

(*f*) Contractor's representatives (technical, contracts, and programme).

Details of the budgeted cost of the project were given in a Development Cost Plan (DCP) which was updated and reissued as required. Meetings were held quarterly at which the team examined progress and expenditure against that set out in the DCP, authorizing any necessary revision to the work package which became apparent; each were subjected to examination against the criteria of cost and effectiveness.

Technical Committee

This team comprised the Project Leader and technical personnel from the Ship Department and from Rolls-Royce Ltd. Meetings were held every six weeks to discuss progress, identify decision points, modify the programme and resolve technical problems. Very close technical liaison has been maintained at professional level, and the importance of this cannot be over-emphasized.

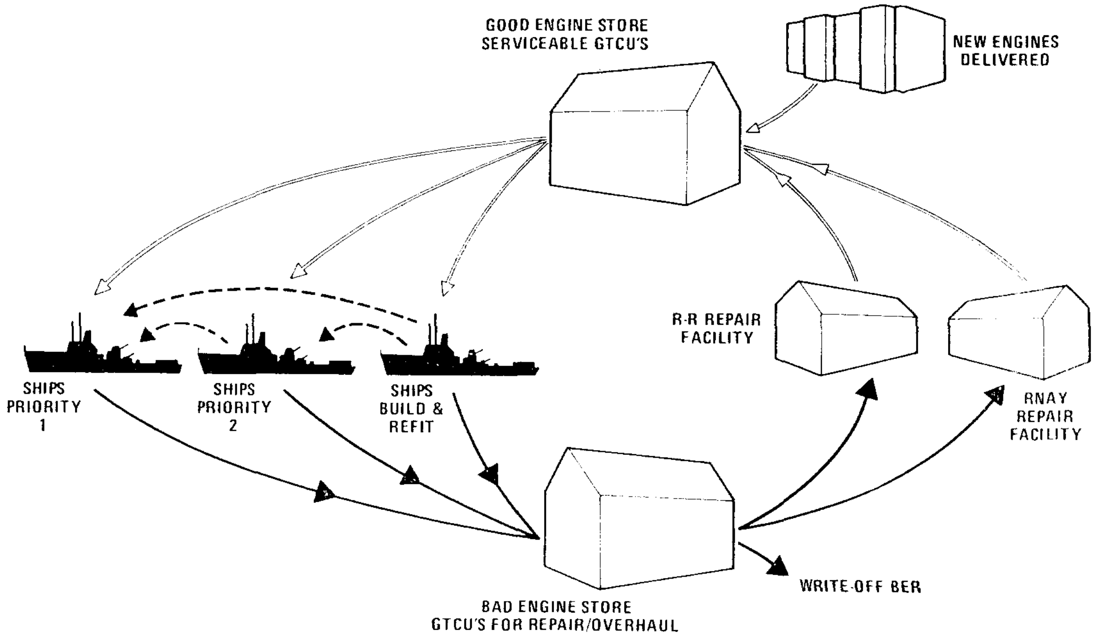

FIG. 1—CONTROL OF GAS TURBINE CHANGE UNITS

Gas Turbine Change Unit (GTCU) Logistic Model

Early in the programme, it was realized that management control over the purchasing of the necessary units for fitting and of spare units would require careful handling if overprovision or the risk of stock-out of these costly units was to be avoided. A computer model simulating the cycle shown in FIG. 1 was produced for estimating the logistic requirements.

The inputs required for this computer are as follows (see also FIG. 2):

(*a*) Ship production programme and corresponding engine fit.

(*b*) Ship operating pattern month by month.

(*c*) Ship priority month by month.

(*d*) Declared overhaul life (DOL) of engines in each year (see *J.N.E.* Vol. 21, No. 1, p. 33).

(*e*) Mean time between failures (MTBF) of engines in each year.

(*f*) Gas turbine change unit (GTCU) delivery programme.

(*g*) Take-on rate at the repair facilities.

(*h*) Turn-round time at repair facilities.

(*i*) Serviceable GTCU stock level at which overtime is initiated in the repair facilities.

The output can be varied but typically would consist of:

(*a*) Monthly statement of serviceable GTCU stock.

(*b*) Monthly statement of failures and of engines achieving DOL.

(*c*) Monthly statement of engines in hand at repair facilities.

The simulation introduces random engine removals, assuming a constant failure rate for each year determined by the MTBF for that year; engines are

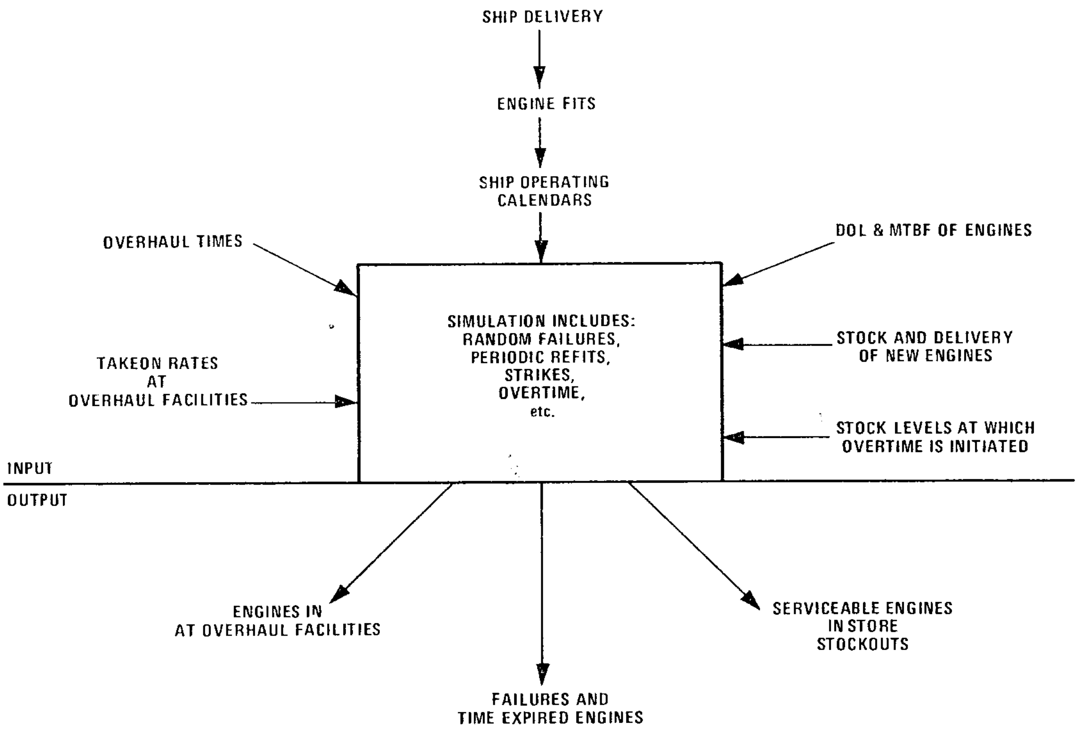

FIG. 2—GAS TURBINE CHANGE UNIT LOGISTIC MODEL

also removed on reaching DOL. The typical variation of MTBF, DOL and mean achieved life (MAL) is shown in FIG. 3. Also included are periodic refits and the effects of randomly occurring strikes and of engines failing beyond economic repair. Overtime is simulated by decreasing the turn-round time at repair facilities, when stocks of serviceable GTCUs fall below a certain number. In the event of total stock out, ships of low priority may be expected to be robbed to keep ships of higher priority at sea.

The model does not indicate explicitly how many spare GTCUs are required; optimization is achieved by comparing the serviceable GTCU stock position predicted by a number of runs, each with a different GTCU buy rate.

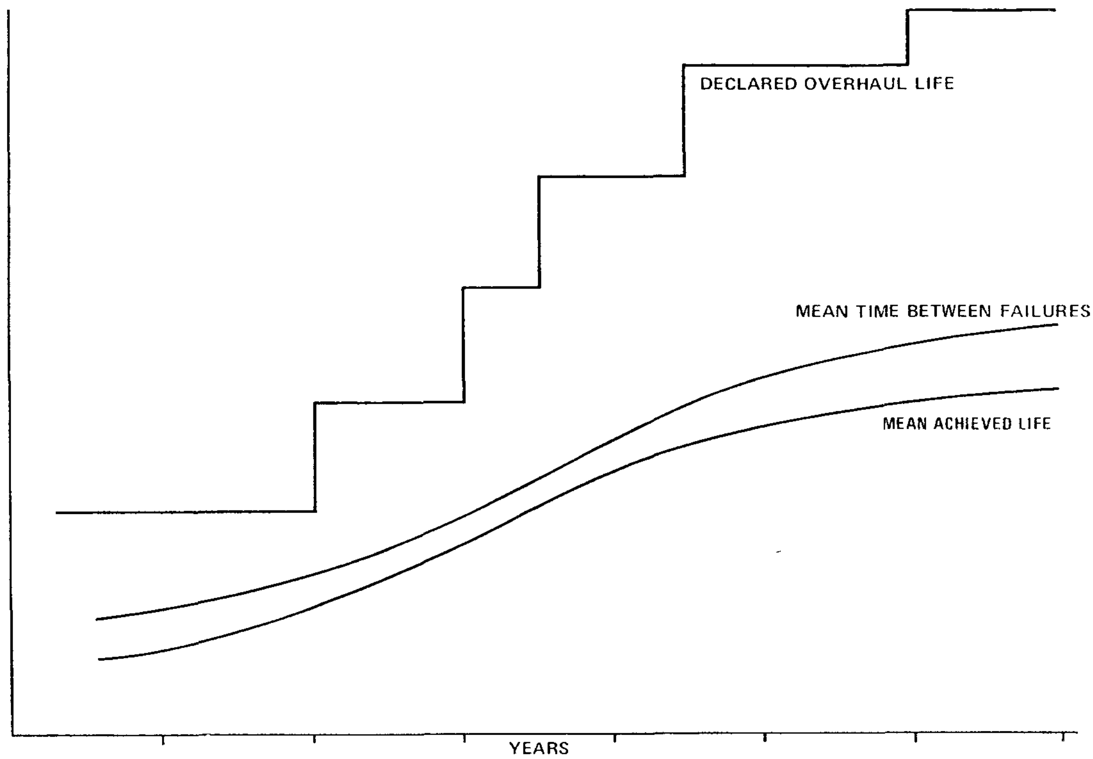

FIG. 3—TYPICAL LIFE TRENDS OF A GTCU UNDER DEVELOPMENT

So far, the model has been used by the Ship Department to estimate the following:

(*a*) The annual buys of GTCUs.

(*b*) The loading of the overhaul facilities in the forthcoming eight years.

(*c*) The forward provision of spares for GTCU overhauls.

At present, the Ministry of Defence is experimenting by using the model as a means of costing alternative support policies, with a view to identifying the most cost-effective level of spares back-up.

Continuing Development

Continuing development is aimed at overcoming in-service problems, improving life between overhauls and reliability. As already mentioned, the Tyne RM1A is being developed into the uprated Tyne RM1C to increase the power, improve tropical performance, and provide greater reliability. Facilities at both Ansty (Rolls-Royce) and the Naval Marine Wing at the National Gas Turbine Establishment are used to carry out development work and to build up the number of hours run. (See also *J.N.E.* Vol. 21, No. 3, p.358.)

Overhaul Facilities

Overhaul facilities are provided at the Rolls-Royce (Industrial and Marine Division) at Ansty and at the Royal Naval Aircraft Yard at Fleetlands. About half of the repair and overhaul work will be done at each place. The Gas Turbine Allocation Authority (see *J.N.E.* Vol. 22, No. 1, p. 9) will control all the serviceable spare engines and also those awaiting repair.

Spares Support

Onboard spares support is provided for work that can be done on board by ships' staff with or without base assistance. The main bulk of spares is maintained at the Spare Parts Distribution Centre (SPDC) and a full stock of overhaul spares is provided at both Ansty and at Fleetlands.

Committees and Working Parties

There are a number of committees and working parties concerned with Olympus and Tyne gas turbine support. These are:

Dockyard Ship Repair Policy Committee (DSRPC).

Marine Gas Turbine Overhaul and Support Working Party (MGTOWP).

Gas Turbine Allocation Authority (GTAA).

Anglo-Dutch-Belgian MOU (Memorandum of Understanding) Working Party.

Anglo-French Collaboration Committee on Olympus.

These committees have wide representations; as a typical example, the MGTOWP has representation from the following:

The Ship Department DWD Ship Sections concerned with each class of ship.

The Ship Department D.Eng. Gas Turbine Section.

The Ship Department Spare Gear Group.

The Director of Fleet Maintenance.

The Head of Aircraft Department (Naval).

The Director General Stores and Transport (Naval).

The Ship Maintenance Authority.

The Chief Executive of Dockyards.

Rolls-Royce (Industrial and Marine Division).

The Director of Naval Ship Production (Assistant Naval Ship Production Overseer at Ansty).

The Royal Naval Aircraft Yard, Fleetlands.

The aims of this particular working party are: 'to ensure that all problems on gas turbine logistic support are foreseen or recognized and that necessary action is taken'.

Modifications

There is a modification problem because the numbers to be processed are clearly going to be far greater than anything previously encountered in the Ship Department (see *J.N.E.* Vol. 21, No. 3, p. 371, for experience with the modification of diesel engines). The situation is being dealt with as follows:

Arising Rates

Initially, 100 modifications are expected per year per engine type; although this should fall to 50 modifications per year per engine type by 1978, it is unlikely ever to be much less than this. This includes modifications to GTCUs, modules and power/speed controllers.

Information needed from Rolls-Royce

Rolls-Royce provide information including laboratory reports, etc. at the stage of identifying a problem; later at the initial scheme stage outline drawings are provided, and a full explanation is provided at the time of submission to the committee. After the committee decision, Rolls-Royce produce a complete submission in the form of a 'Product Improvement Bulletin' which includes costs, effect on books, drawings, spares, etc.

Internal Procedure

On receipt of a Product Improvement Bulletin, information is passed to all the parties concerned, who meet regularly at a Modification Approval

Committee chaired by the Assistant Director responsible for propulsion plant. When approved, modification action follows the standard Ship Department procedure.

Staff Required

The secretariat of the Modifications Committee and the staff required to co-ordinate all actions is provided by the Ship Department. The fulfilment of the procedure also requires staff from other sections of the Ship Department.

Effect of Modifications on Spares

A special sub-committee with representation from Rolls-Royce, the Gas Turbine Section and the Royal Naval Aircraft Yard is being set up to process the initial provisioning of all spares needed for modifications; this includes on-board, SPDC, Depot Spare Machinery, and repair spares. This sub-committee, which has not yet started work, has a great deal to do.

Liaison with Other Users

Operators of the common pool of engines are consulted before modifications are approved. Other engine users are kept informed of these modifications. The present proposal is that users of the common pool should all receive copies of the Product Improvement Bulletins from Rolls-Royce at the same time as they are received in the Ship Department. Should these users have any doubts regarding a modification, they may inform the secretary of the Gas Turbine Modification Committee. A steering committee comprising senior representatives of the three navies (the R.N's representative is the Assistant Controller of the Navy) will arbitrate where there is disagreement.

Liaison with Other Departments

All information on modifications is distributed to other interested parties (Ship Sections, Support Managers, etc.). The Chief Executive Dockyards is automatically informed of any modications with which he has a concern.