LOGISTIC SUPPORT OF MARINE GAS TURBINES

ROYAL NAVY EXPERIENCE

BY

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This article was originally prepared at the invitation of the American Society of Mechanical Engineers and was presented by the author at the A.S.M.E. Gas Turbine Conference held at New Orleans, Louisiana in March 1980.

Introduction

Although Rolls-Royce Olympus and Tyne marine gas turbines are fitted in ships of sixteen navies, the Royal Navy is intimately concerned with only four of these—itself and the navies of Holland, Belgium and France. The reason is that these four countries not only operate a common logistic support system for these engines but they actually share the ownership of spare engines and spare parts. The Royal Navy manages this common logistic system on behalf of its partners.

The background and early stages of setting up this gas turbine logistic support system, restricted at the time to the Royal Navy only, were outlined in a previous paper[1]. Subsequently Wright[2] described it in more detail, paying particular attention to its theoretical basis and the planning of support. The emphasis of this article is on experience in multi-national gas-turbine support and some of the procedures used in it.

In discussing the subject it is best to consider first those aspects that would apply even for a single Navy and then to take separately the additional complications that arise because of international ownership and use.

For one Navy (and equally for a group of navies) systems and procedures are needed for:

(*a*) predicting requirements of spare engines and spare parts;
(*b*) initial provisioning;
(*c*) re-provisioning as use occurs;
(*d*) repairs;
(*e*) identifying priorities in manufacture and repair and accelerating when necessary;
(*f*) identifying delays in manufacture and repair and rectifying where necessary;
(*g*) allocation and issue.

On the face of it, it might seem that normal store-keeping practices should be adequate to meet these requirements. With aero-derived gas turbines, however, several factors cause the systems to be more complex and hence more interesting:

(*a*) The nature of spares usage in ships and in the overhaul facilities makes re-provisioning by past usage more suitable for the former while the latter needs predictive re-provisioning.
(*b*) A number of components have finite lives in terms of running hours.
(*c*) Changing modification states require special control of spares.
(*d*) The spare engines (the gas turbine change units) are controlled in a specially tight manner because:

(*i*) their high value make it important that they are not delayed in transit at any time;
(*ii*) individual engines have different lives either because of their modification states or because they are part used;
(*iii*) interchangeability between the engine and the ship can sometimes be affected by the modification state;
(*iv*) specialist change teams of naval ratings are usually sent to carry out engine changes.

The four partner navies (Royal Netherlands Navy, Belgian Navy, French Navy and Royal Navy) use Royal Navy procedures and documentation in nearly all cases. Some of these systems have had to be modified, however, to take account of certain aspects of joint ownership. These include:

(*a*) procedural changes resulting from multi-national use, e.g.
  (*i*) assured impartiality of allocation and issue;
  (*ii*) some degree of dispersed stocks on the mainland of Europe;
  (*iii*) the need occasionally to replace with a jointly-owned engine one which had been bought by a foreign shipbuilder and then failed while in a new ship.

(*b*) stores accounting and financial changes necessary to ensure equitable cost sharing between the navies.

Gas Turbine Change Units

The gas turbine change units (GTCUs) comprise the main body of the gas turbine, derived from its aero predecessor, which can be lifted out complete from the ship.

Although it is often loosely referred to as 'the engine', there remains in the ship not only the bedplate and enclosure but much of the controls system, gearing, etc. and, in the case of the Olympus, the power turbine also.

Predictions of the numbers of GTCUs needed as spares are made by a computer simulation taking account of ship usage, engine reliability, overhaul duration, etc. (see p. 5 of Ref. 2).

The task of allocating GTCUs to ships is done by a small group in the MOD, Bath, the Gas Turbine Allocation Authority. All four partner navies have the right to participate in its work, both to ensure impartiality and to share the work load, but at present it is manned only by Royal Navy people with part time assistance of a Netherlands officer who works in Bath.

All the GTCUs held by the four navies, whether installed, under repair, or serviceable spares, are displayed on boards (FIG. 1) as an aid to allocation. While every effort is made to keep all GTCUs similar, individual ones sometimes differ by virtue of their modification state or life remaining, and allocation takes account of this. The question of 'interchangeability modifications' that affect the ability of some GTCUs to be fitted in certain ships is discussed later. Where possible, engine changes are planned ahead so that refits or maintenance periods can be utilized to replace GTCUs that have reached the end of their planned lives. In cases of premature failure, of course, this is not possible. In both cases the procedures are similar and include making arrangements for special transport and for attendance of specialist engine change teams.

Future sufficiency of serviceable spare GTCUs has to be constantly checked. The lead time of new engine supply is such that if significant changes in usage, reliability, or overhaul duration take place after new orders have been based on the computer simulation prediction, shortages could occur. Short term simulations (e.g. two years and less) are therefore done fairly frequently using the latest data.

IN SERVICE

ROYAL NAVY

	MODULE SERIAL NUMBER	INSTALLED GTCU SERIAL NUMBER
42 01 SHEFFIELD	P 09	901011 JUL 80
	S 06	901051 JUL 80
02 BIRMINGHAM	P 25	901062 APR 80
	S 24	901003 APR 80
03 CARDIFF	P 07	901058 OCT 77
	S 16	901056 NOV 77
04 COVENTRY	P 19	901039• MAY 77
	S 18	901049 MAY 77
05 NEWCASTLE	P 31	901026• OCT 79
	S 30	901009 MAY 80
06 GLASGOW	P 37	901057 OCT 77
	S 36	901055 OCT 77
07 EXETER	P 55	901028 JUN 79
	S 44	901063• DEC 79
→ 08 SOUTHAMPTON	P 57	901023 MAY 80
	S 54	901024• MAY 80
09 NOTTINGHAM		
10 LIVERPOOL		
21 01 AMAZON	P 01	901027 APR 79
	S 02	901016 APR 79
02 ANTELOPE	P 04	▬ 901036 NOV 79
	S 03	▬ 901035• NOV 79
03 ACTIVE	P 10	901029• OCT 79
	S 08	901047 JUN 80
04 AMBUSCADE	P 14 ◄	
	S 11 ◄	
05 ARROW	P 23	901015• OCT 78
	S 22	901013 APR 79
06 ALACRITY	P 27	901012 MAR 79
	S 26	901008 MAR 79
07 ARDENT	P 33	901041• MAR 80
	S 32	901025• SEP 79
08 AVENGER	P 35	901046 JUN 77
	S 34	901045 JUN 77
22 01 BROADSWORD	P 39	901060▼ FEB 78
	S 38	901059▼ FEB 78
BATTLEAXE	P 41	901019▼ MAR 79
	S 40	901030▼ FEB 79
BRILLIANT	P 43	901004 JUN 80
	S 42	901043 JUN 80

ROYAL NETHERLANDS NAVY

	MODULE SERIAL NUMBER	INSTALLED GTCU SERIAL NUMBER
GMF		
01 TROMP	P 13	901050 JUN 78
	S 12	901014 MAR 80
02 DE RUYTER	P 21	901006 FEB 79
	S 20	901052 APR 79
S		
01 KORTENAER	P 47 ◄	902015 DEC 78
	S 46 ◄	902007 MAY 79
02 CALLENBURGH	P 49 ◄	902010 OCT 78
	S 48 ◄	902020 OCT 79
03 VAN KINSBERGEN	P 51 ◄	902016 SEP 79
	S 50 ◄	902019 SEP 79
04 BANCKERT	P 53	902013 MAR 80
	S 52	902002 MAR 80
05 PIET HEYN	P 59	
	S 58	
06 PIETER FLORISZ	P 61	
	S 60	
07 WITTE DE WITH		
08 ABRAHAM CRIJNSSEN		
09 PHILIPS VAN ALMONDE	P 72 ◄	
	S 71 ◄	
10 BLOIS VAN TRESLONG		
11 JAN VAN BRAKEL		
12 WILLEM VAN DER ZAAN		

KEY

INTERCHANGEABILITY MODIFICATIONS	MODULE MOD NO	GTCU MOD NO	
◄ RMIC CONVERTED MODULE			MOD 294 2000 HR CANS ●
▼ ANTI ICING VV INLET DUCT MANDATORY TYPE 22		736	MOD 873 CANS •
			MOD 874 BURNERS ▬

FIG. 1A—ALLOCATION BOARD FOR TYNE GTCUs

IN POOL

SERVICEABLE				UNSERVICEABLE	
ACTUAL HRS REMAINING			REMARKS	FLEETLANDS	ROLLS ROYCE
	902004▼	SEP 79	RNLN **A**	901022• TROMP REPAIR MAR 80	901038■ REFURBISH JUL 80
	902632	DEC 79		901007• ARDENT REPAIR APR 80	902011 AMBUSCADE REFURBISH APR 80
	902009	APR 80			
	902006	MAY 78	FLTNDS **A**		
	902008	JAN 78	RNLN **A**		901005 BIRMINGHAM RMIC CONVERSION APR 80
	902001	OCT 79	**A**		
	902012	MAY 80			901018 BIRMINGHAM RMIC CONVERSION APR 80
	902642	JUN 80	FLTNDS		
				901040 NEWCASTLE RMIC CONVERSION JAN 80	902005 AMBUSCADE REPAIR AND REFURBISH JUL 79
	901054	MAY 80	FLTNDS		
	901048	JUL 80			
	901053▼	MAR 80	RNLN **A**	901044• NEWCASTLE REFURBISH MAY 80	
	901031•	JUL 80	FLTNDS		
					901017 ANTELOPE REFURBISH AUG 79

IN TRANSIT	ON LOAN	
901037▼ ARROW	901010 HMS SULTAN	TRAINING AID
	DEVELOPMENT	
	904001	ANSTY
	003	ANSTY
	004	ANSTY
	209002	PYESTOCK
	905002	PYESTOCK

FIG. 1B—ALLOCATION BOARD FOR TYNE GTCUs

Predictions are also made manually using planned dates of engine changes, repair completions, and new deliveries. If impending shortages were to be predicted, then several options would be open ranging from extending the planned overhaul life (and thus hopefully delaying the need for a replacement until after the shortage has passed) to deliberately making greater use of the other engine type in the ships' COGOG installations.

Overhaul of GTCUs takes place either at the manufacturers (Rolls-Royce) or at the Royal Naval Aircraft Yard at Fleetlands. The depth of overhaul can range from a full re-condition, through a re-condition of the hot end only or a specific repair, to an uninstalled servicing. In all these cases modifications can be incorporated and the decision as to which of the approved modifications should be fitted is made by the Gas Turbine Allocation Authority at the time it allocates the GTCU to one or other of the overhaul facilities. Factors taken into account in the decision include the intrinsic importance of the modification, the depth of strip necessary and the extent to which the engine will be stripped anyway, and also any shortage of GTCUs necessitating the shortest possible turn round time.

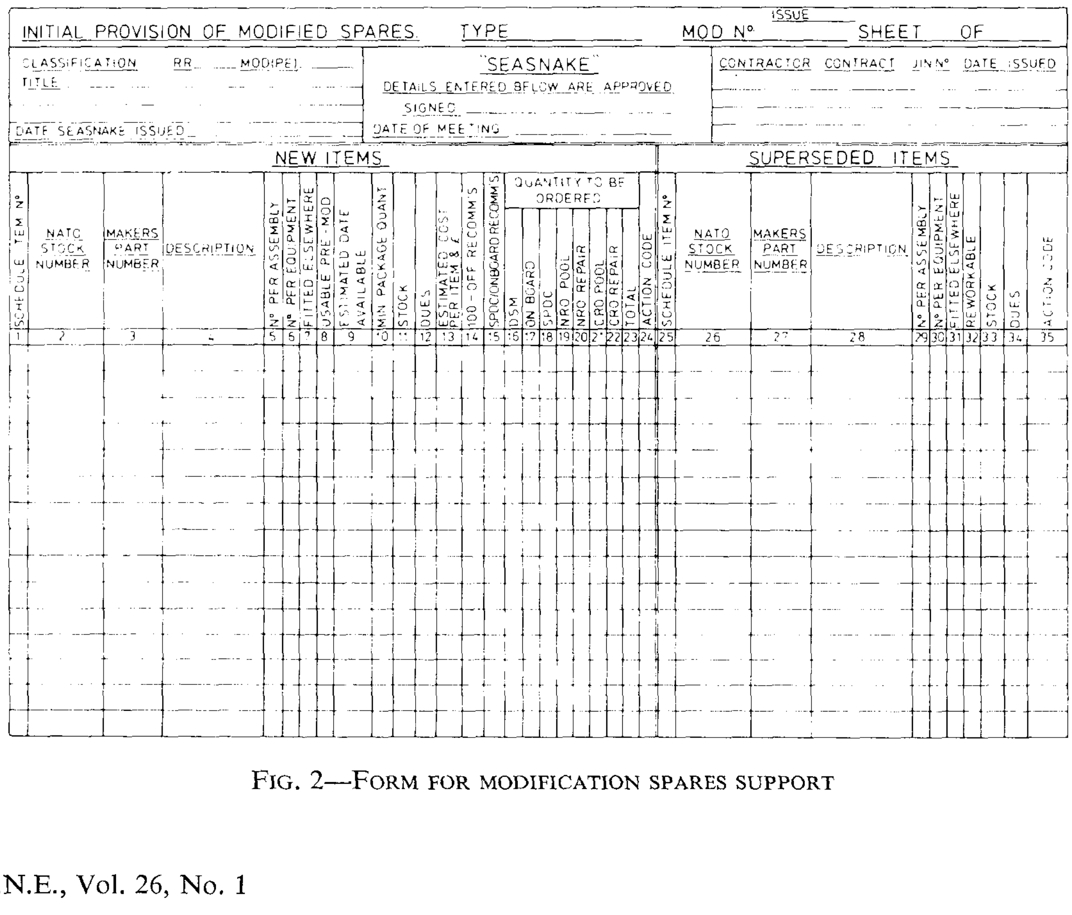
Occasionally, to effect an improvement in the design of an engine, it is necessary to modify both the GTCU and the module remaining in the ship. This may result, transitionally, in the position where certain ships are capable of receiving certain GTCUs only, with consequent constraints on the allocation of replacement GTCUs. Such 'interchangeability mods' are denoted by special symbols such as triangles or other shapes on the allocation boards (FIG. 1), so that even an emergency issue by a weekend duty officer will take account of them.

Typical interchangeability modifications include:

Tyne

(*a*) A modified lubricating oil supply hose was needed in the onboard module to match the modified arrangement introduced in the GTCU to avoid frettage of the self-sealing coupling.

(*b*) To avoid fuel leakage problems, the self-sealing couplings at the GTCU/ module interface were reversed.


INITIAL PROVISION OF MODIFIED SPARES. TYPE MOD N° ISSUE SHEET OF

CLASSIFICATION RR MOD(PE) TITLE DATE SEASNAKE ISSUED

"SEASNAKE" DETAILS ENTERED BELOW ARE APPROVED SIGNED DATE OF MEETING

CONTRACTOR CONTRACT JIN N° DATE ISSUED

NEW ITEMS																								SUPERSEDED ITEMS										
															QUANTITY TO BE ORDERED																			
SCHEDULE ITEM N°	NATO STOCK NUMBER	MAKERS PART NUMBER	DESCRIPTION	N° PER ASSEMBLY	N° PER EQUIPMENT	FITTED ELSEWHERE	USABLE PRE-MOD	ESTIMATED DATE AVAILABLE	MIN PACKAGE QUANT	STOCK	DUES	ESTIMATED COST PER ITEM & £	100-OFF RECOMM'S	SPDC/ONBOARD RECOMM'S	DSM	ON BOARD	SPDC	NRO POOL	NRO REPAIR	CRO POOL	CRO REPAIR	TOTAL	ACTION CODE	SCHEDULE ITEM N°	NATO STOCK NUMBER	MAKERS PART NUMBER	DESCRIPTION	N° PER ASSEMBLY	N° PER EQUIPMENT	FITTED ELSEWHERE	REWORKABLE	STOCK	DUES	ACTION CODE
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35

FIG. 2—FORM FOR MODIFICATION SPARES SUPPORT

(*c*) Resiting of a vibration transducer from the GTCU to the module was necessary to ease GTCU changes.

(*d*) Modification of the overspeed probe unit on the GTCU necessitated a revised electrical layout in the module.

Olympus

(*e*) Improvements in the GTCU fuel system to overcome idling speed variations necessitated the onboard module being fitted with a pressurizing valve, filters, and associated pipe work changes.

(*f*) A smoke reducing modification to the burners required a deceleration control system to be fitted in the module to prevent flame blow-out during slam decelerations.

In the case of (*e*) and (*f*) the modules can be modified independently so that they are able to accept GTCUs of either modification state. For (*a*), (*b*), (*c*), and (*d*), though, GTCU and module modifications have to be fitted at the same time; they are not lengthy.

Spare Parts

Spare parts are needed for four kinds of work:

(*a*) Repairs onboard ship by the crew.

(*b*) Repairs of certain components by naval dockyards.

(*c*) Repairs of certain components by their manufacturer. Normally the firm uses its own commercial stock so the Royal Navy does not need to provide spares.

(*d*) Repairs of GTCUs and certain other components by the overhaul facilities, Rolls-Royce and Fleetlands.

The spares needed for (*a*) and (*b*) are held by the Royal Naval Spare Parts Distribution Centre at Eaglescliffe or the Royal Naval Store Depot at Llangennech just like machinery spares for any other ship equipment. An initial supply of spares was bought based on the manufacturers' recommendation. For repairable spares additional purchases should not normally be needed but for the rest re-provisioning is done in the normal way based on past usage. The number of replacement spares is not necessarily the same as the number used but takes account of the rate of usage so that changes in reliability or Fleet size are reflected. The size of the initial stock is planned to be large enough to allow this automatic re-provisioning system to be effective.

The spares needed for GTCU overhaul and repair are more extensive and expensive than those in the other categories. Furthermore the computer simulation model already mentioned in connection with GTCU purchase also predicts the rate at which overhauls and repairs will occur. This makes it possible to order spares to meet the intended programme. The programme for a suitable period ahead is combined with a '100-Off list' or manufacturers' recommendation of the quantity of spares expected to be used when overhauling a typical mix of a hundred defective or life-expired engines or components. This 100-Off list is constantly revised in the light of actual usage but essentially the re-provisioning system for overhaul spares is based on prediction.

All spares procedures—issuing no less than provisioning—are complicated by modifications. The number of modifications deliberately introduced in aero-derived gas turbines to take advantage of modern technology and to increase their lives makes this no small problem. The purchase, disposal, and rework (i.e. conversion) of pre-mod and post-mod spares can only be dealt with adequately by meticulous and detailed examination of the effect of each modification on spares support. Conscious decisions have to be made for each spare concerned and the need for each decision is systematically highlighted by the way in which

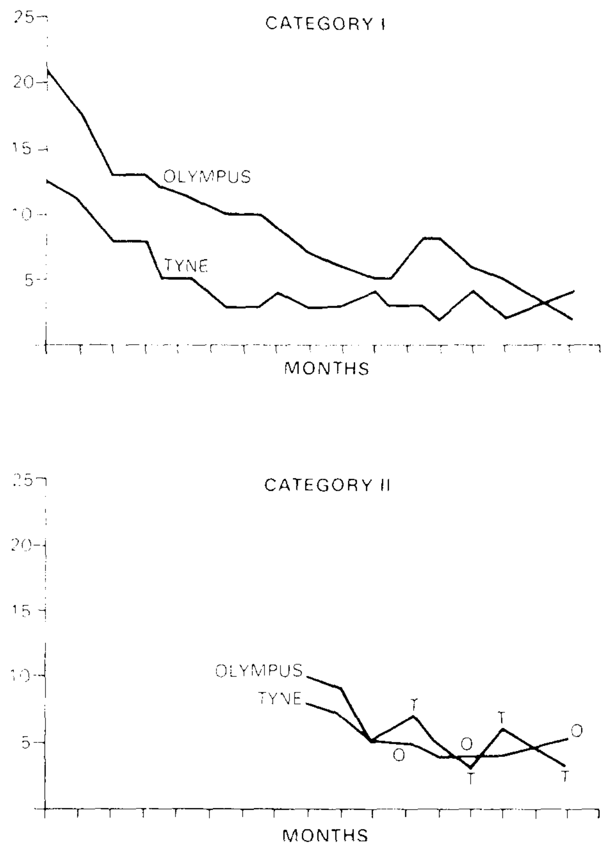


FIG. 3—SPARE PARTS IN CRITICALLY SHORT SUPPLY

the spares support changes are documented. A form for each modification (FIG. 2) lists the entire pre-mod support (on the right) and post-mod support (on the left), together with all the information needed for the decision making. The fact that most modifications are introduced into the Fleet gradually means that both pre-mod and post-mod states have to be available at the same time for a period. Typical decisions for pre-mod parts might be 'rework to post-mod standard', 'transfer dues-in to new standard', 'retain for pre-mod engines' or 'dispose of'. For post-mod parts it might be recorded that sufficient are already held from some other source, or that the requirement will be met by reworking the pre-mod stock or that so many need to be bought.

Inevitably certain spares become critically short from time to time, whether because of excessive use, inadequate ordering or delays in repair or manufacture. Lists of such 'critical spares' are drawn up every three months or more frequently; they are based on records of stock and demands and then pruned subjectively on technical grounds. The definition used in preparing these lists is:

> 'Critical spares are those spares which warrant special and vigorous progressing action on production and repair programmes because they support technically vital components and are at a stock level that is unlikely to meet forecast demands in the next year.'

They are in two categories:

(*a*) Category 1: needed for keeping engines operational in ships.

(*b*) Category 2: needed for engine overhaul or onboard outfits of spares.

All items on the critical lists are given special management attention by the manufacturer, hastened as necessary from his sub-contractors and accelerated through the despatch line. Similar action is taken for any which are under repair. At the same time information about any held independently in the base stocks of partner navies is passed to the Gas Turbine Allocation Authority.

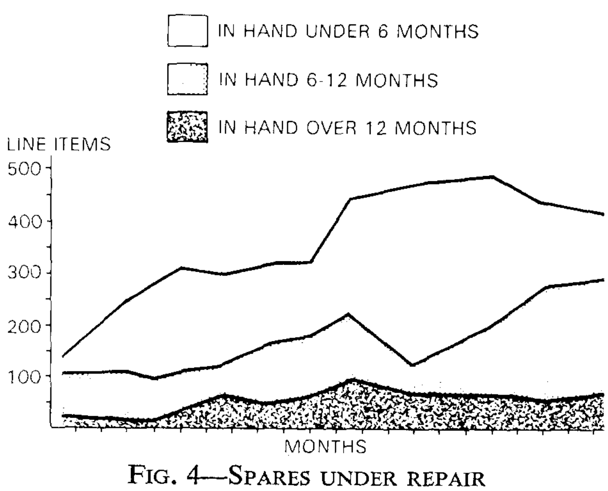


FIG. 4—SPARES UNDER REPAIR

As in any management system, it is necessary to watch trends in the supply, repair, and availability of spares so that general weaknesses can be identified and rectified before they become serious. Four examples of such trend plotting are considered here:

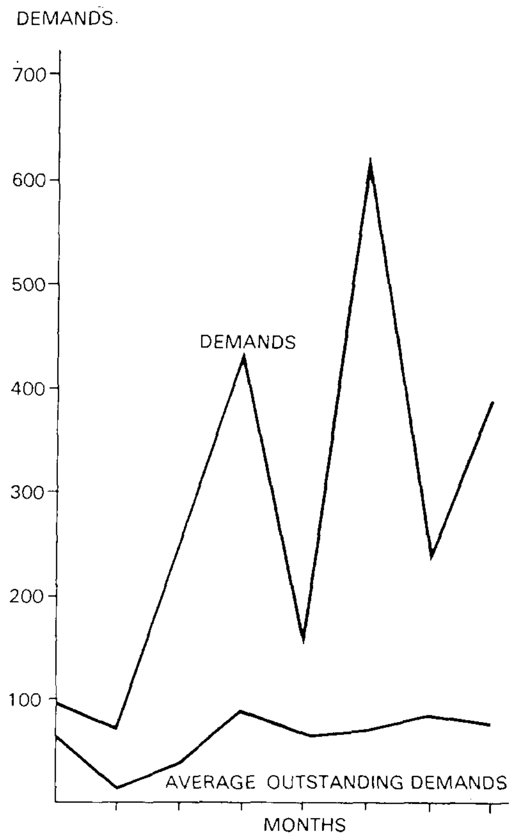


FIG. 5—EFFECTIVENESS OF OVERHAUL SPARES STORE (NON-COMPUTERIZED)

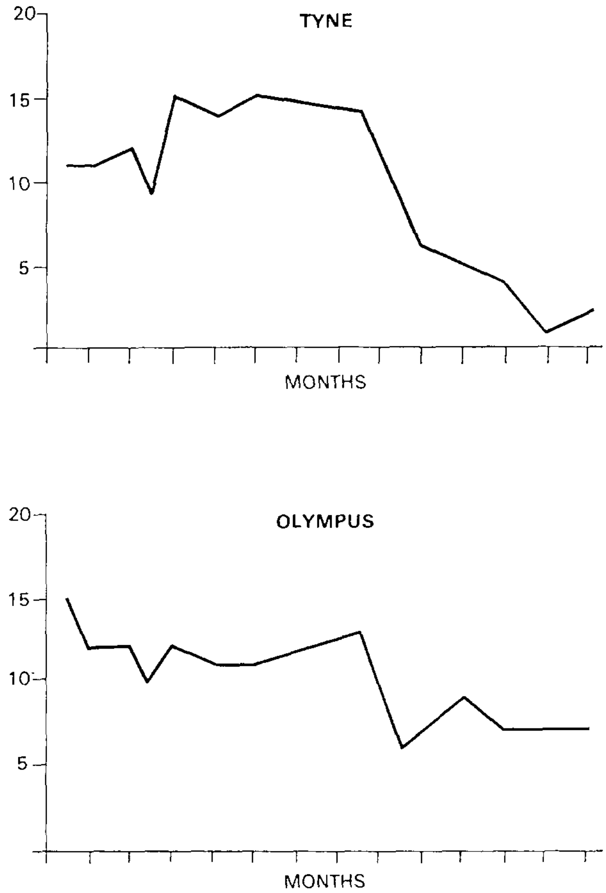


FIG. 6—MODIFICATION KITS IN CRITICALLY SHORT SUPPLY

(*a*) The number of spares deemed to be in critically short supply (e.g. FIG. 3). It should be emphasized that ships have not actually been delayed by lack of these critical spares; in every case special procurement or at worst 'robbing' from a spare engine has met the really vital demands and this has very rarely been necessary.

(*b*) The number of spares under repair and the time spent in repair (FIG. 4). As a result of further analysis a number of management bottlenecks were identified and the originally worsening situation brought under control.

(*c*) The effectiveness of the various stores. This can be measured in several different ways where computerized stock control makes the information readily available. Thus at the Rolls-Royce overhaul facility the effectiveness of the store is measured in two ways:

(*i*) The proportion of items in its range of which stock is held.

(*ii*) The percentage of demands met within one week, 4 weeks, 8 weeks, etc.

At the Royal Naval Aircraft Yard Fleetlands, fully computerized stock control for marine gas turbines has not yet been introduced so a different method has to be used. Even so, however, it is clear from FIG. 5, where monthly totals of demands are compared with the average number of outstanding demands held during the month, that the store is preventing the latter figure from increasing despite the rise in demands and issues. Thus, its effectiveness is increasing.

(*d*) The number of modification kits in critically short supply (FIG. 6).

Difficulty can be experienced if modifications are fitted in new engines before the spares back-up is available, or if the modification kits are ready to be incorporated before the necessary instructions have been issued as a 'mod leaflet'. To facilitate the planning and monitoring of all these four aspects they are correlated on single planning charts which also serve readily to indicate whether an approved modification is yet ready to fit.

International Logistic Support

The GTCUs and nearly all the spare parts for the Olympus are owned jointly by the navies of Great Britain, Holland, Belgium and France. The Tyne is not used by the Belgians or French so only the Royal Netherlands Navy and the Royal Navy share ownership of its GTCUs and spares.

This joint ownership of a common pool of engines and spares has three main purposes:

(*a*) It allows more flexible use of the material.

(*b*) It permits a smaller overall stock to be held than would be needed by all the navies acting independently, thus reducing cost for each country.

(*c*) It enhances and develops the spirit of collaboration between these countries.

Common ownership of GTCUs requires joint acceptance of all GTCU modifications and this is arranged. Individual GTCUs are likely to have different modification states at any given time though, depending on which modifications have by then been incorporated in them. The rest of the equipment, i.e. the on-board modules, is kept as similar as possible in the interest of common spares support but there are a few national differences, none of them affecting the interchangeability of the GTCUs.

In 1975 when the joint logistics system began, Holland and Belgium 'bought in' to the spares pool already established by the Royal Navy. This was enlarged suitably to meet the increased needs. The French Navy has joined more recently, buying itself in to the already existing tri-national pool of spares.

Spare parts are demanded by all four navies using Royal Navy demand forms. On each occasion the accounting system then charges the user for the cost of buying a replacement part to maintain the spares pool at its existing size. The cost of any increase in size of the pool, necessitated for example by a greater usage rate or increased Fleet sizes, is shared between all the countries concerned in an agreed ratio related to the number of engines which each navy would have needed had it operated alone. This ratio is reviewed periodically. Some rather complex calculation is needed to ensure that changes in the size of the pool are accurately reflected in the charges raised.

GTCUs are also demanded by all four navies using the pre-existing Royal Navy system. They are allocated with equal priority. It would be unfair for the cost of overhaul of an engine to fall to the Navy in whose ship it was when it failed. Rather, the total cost of all the GTCU overhauls (labour and spares) throughout the year is added together and apportioned between the navies in an agreed ratio which is based on the total hours run by all GTCUs in each Navy in that year.

This refined method of sharing costs is not suitable for the generally much cheaper repair of spare parts. When unserviceable spares are returned, the sender is credited with a fixed proportion of the cost of the new part, i.e. he is in effect paying a flat rate charge for the repair of each item whether the actual repair costs more or less. Over the year this proves equitable and running checks are made to see if the percentage flat rate needs adjusting.

In any of the countries there may be certain individual engines (e.g. engines used for development work) which are nationally and not jointly owned. The cost of repairs to these and spares used on them has to be kept quite separate to prevent wrongful sharing of such costs.

An even more complicated situation arises when a new engine fitted in a new ship by a national shipbuilder fails during trial and while under guarantee. Its repair is then contractually a national liability but the replacement is provided from the common pool. The contractual and international complexities of this are interesting. From the stores management point of view, it is necessary also to take special steps in the supply of spare parts for the repair of such an engine to ensure that the cost of spares is not inadvertently shared between the partner navies not concerned.

Those were some of the major problems arising from international ownership of spares and they have been resolved. Smaller problems for which special procedures are currently being devised include:

(*a*) separate identification of the proceeds when disposing of scrap or obsolete parts so that credits can be shared between all the joint owners;

(*b*) sharing the cost of any losses or stock discrepancies occurring while in 'international' stores;

(*c*) how to deal with those relatively few spares which are common to other equipment and which hence cannot be wholly owned in the usual way by the partner navies.

Conclusion

Experience over more than four years has shown that shared use and joint ownership of gas turbine spares works effectively and advantageously to all the partners. Not only has it resulted in real benefits to all the navies but it has also proved a stimulating and enjoyable challenge to the engineers and others concerned in all four countries.

Acknowledgements

The author acknowledges with thanks the assistance of colleagues in the Ministry of Defence. Any views expressed are those of the author and are not necessarily those of the Ministry of Defence.

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