SPEY SM1A MODULAR REPAIR EXPERIENCE

BY

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ABSTRACT

The Rolls-Royce Spey SM1A marine gas turbine has been in service with the Royal Navy since 1985. This article outlines the repair processes used on the engine and discusses some of the problems experienced in service that have led to engines being removed from ships for repair.

Introduction

The Rolls-Royce Spey SM1A gas turbine, a marinized version of the successful aero engine of the same name, first went to sea with the Royal Navy in 1985 installed in HMS *Brave*. Since then it has been fitted in four Batch III Type 22s, and in Type 23 01, 02, 04, 05 and 06, and it will be fitted in Type 23 07, 08 and 09. HMS *Brave* has recently been retrofitted with the Spey SM1C[1], an uprated, improved version of the SM1A which has been chosen as the boost engine for Type 23 10 et seq., and therefore the RN SM1A-equipped fleet will eventually total 12 ships.

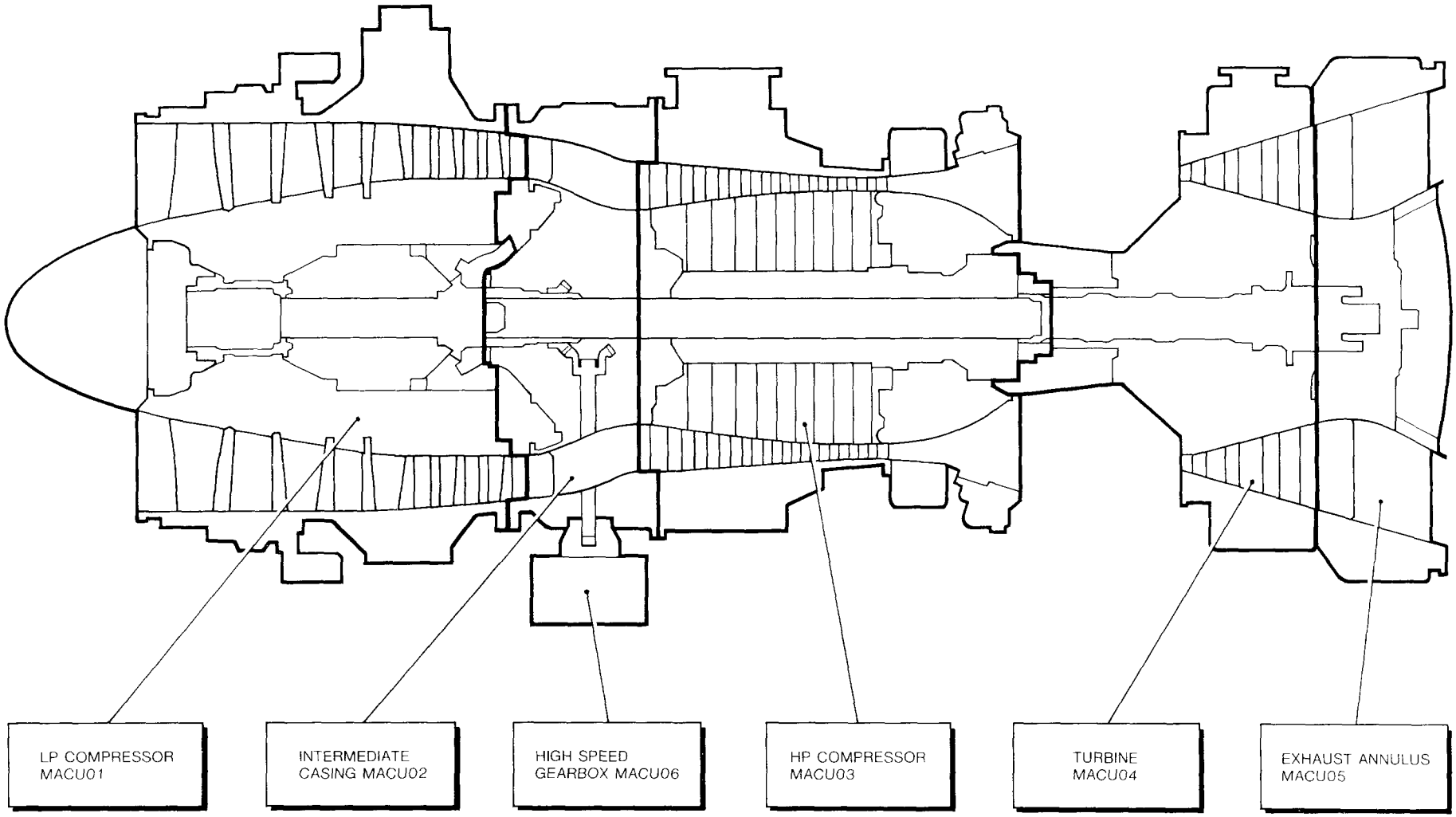


FIG. 1—MARINE SPEY SM1A MAINTENANCE ASSEMBLY CHANGE UNITS

The Modular Gas Turbine

Whereas the SM1A is a successor to the Rolls-Royce Olympus, it differs quite markedly in terms of construction and hence in terms of repair. The SM1A is a modular engine, meaning that it is transversely separated into a series of discrete sections termed Maintenance Assembly Change Units or MACUs which can be replaced independently, when either defective or time-expired, with a serviceable unit of the same type. This concept, known as Maintenance Assembly Exchange, or MAX, is a well-proven technique from the aero and industrial gas turbine worlds and the SM1A is the first RN marinized engine to adopt the idea. The main attraction of MAX over conventional gas turbine repair techniques is that repair times can be reduced significantly since rectification of a defective Gas Turbine Change Unit (GTCU) becomes limited to the substitution of a serviceable MACU or MACUs. The in-depth repair of the physical defects within the rejected MACUs can be undertaken after the parent GTCU has left the repair shop as a fully serviceable unit.

FIG. 1 shows diagrammatically the six MACUs which make up an SM1A GTCU whilst FIG. 2 shows a complete unit together with a full 'set' of MACUs but it should be noted from the latter illustration that a GTCU comprises more than just the six MACUs. All the additional ancillary equipment such as the fuel and oil systems are treated as separate entities not part of any MACU and they are not included in a MAX except where an item is found or reported defective e.g. a fuel pump. They are otherwise only removed, in whole or in part, to allow sufficient access to carry out the required MAX operation. In addition to the

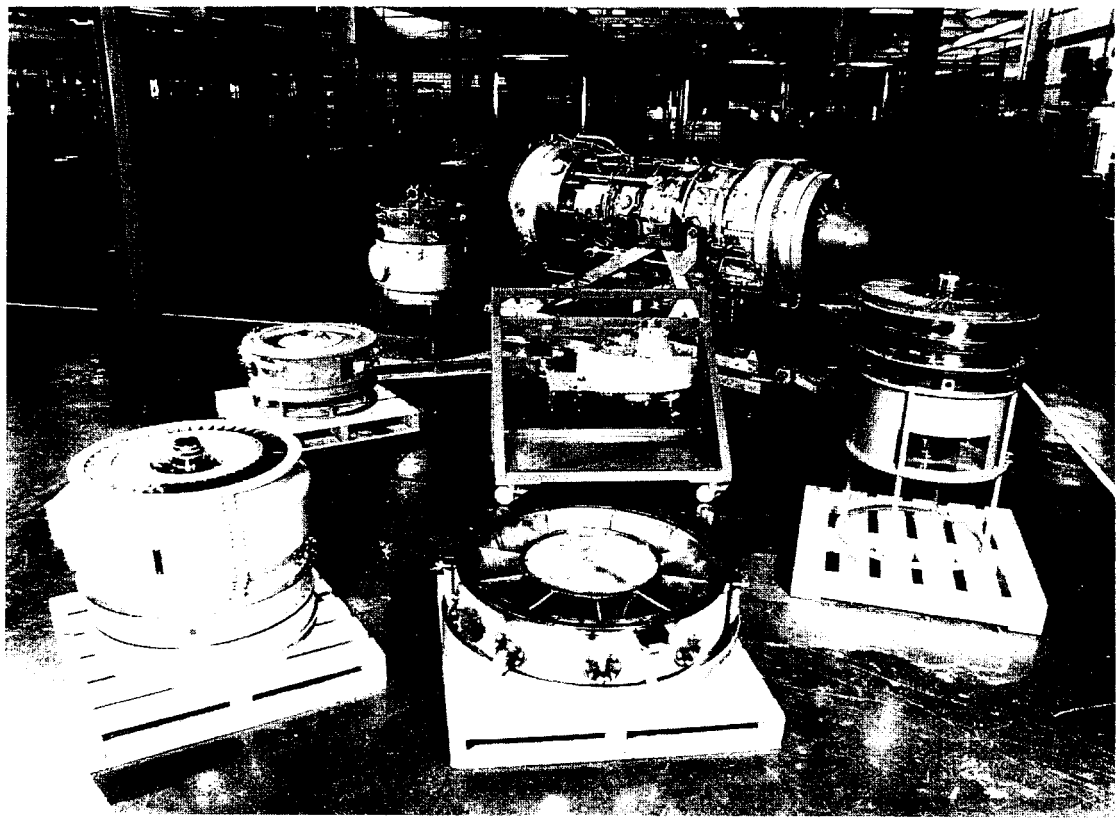


FIG. 2—SPEY SM1A GTCU AND A SET OF MACUS

GTCU

03

02

06

04

01

05

MACUs and ancillaries, there exists a kit of parts consisting of various fastenings and casing assemblies, termed attaching parts, which, as their name suggests, hold the MACUs together to form the bulk of the GTCU. These attaching parts are often referred to collectively as 'MACU07'.

Maintenance Assembly Exchange is carried out at Rolls-Royce's repair and overhaul facilities at Ansty near Coventry and the Company has designed and manufactured a suite of special tools which enable any combination of MACU exchanges to be carried out. A series of MAX operations were demonstrated to the Ministry of Defence in 1986, following which the decision was taken to embrance the concept for all subsequent repair and overhaul of RN Spey SM1As. The RN's existing SM1As were converted to modular construction to match the subsequent standard of new build engines.

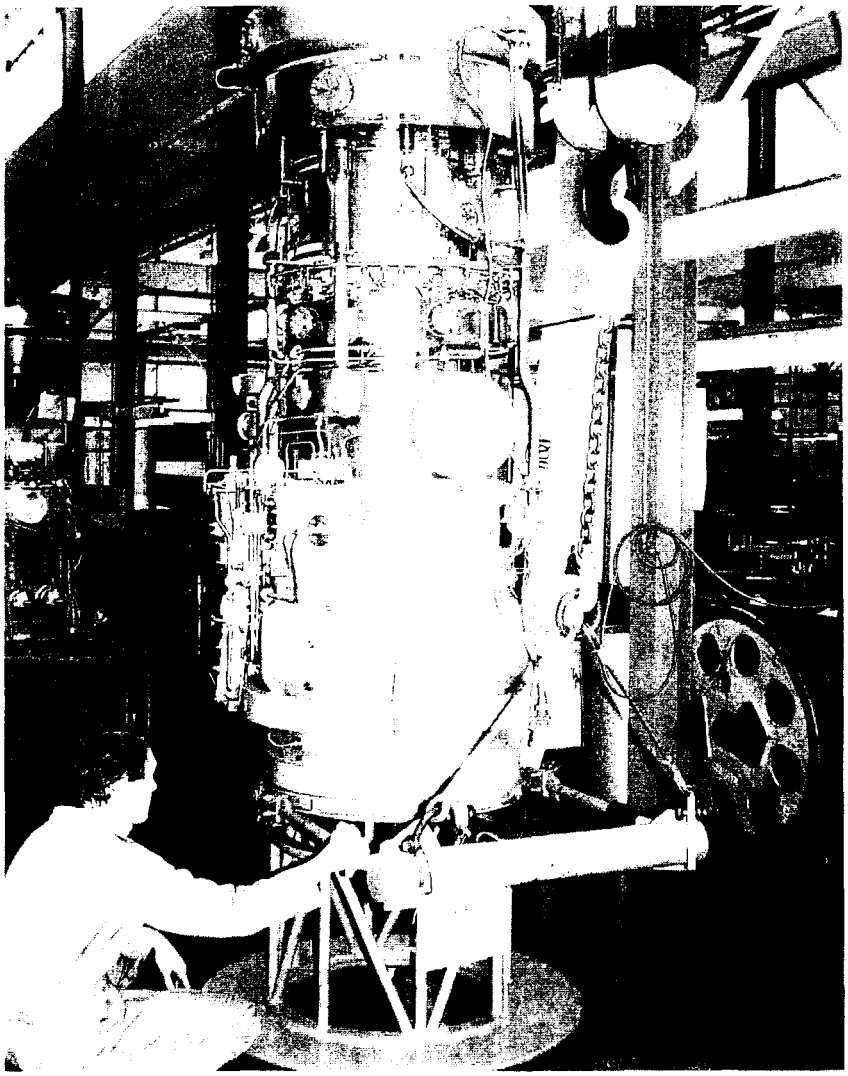
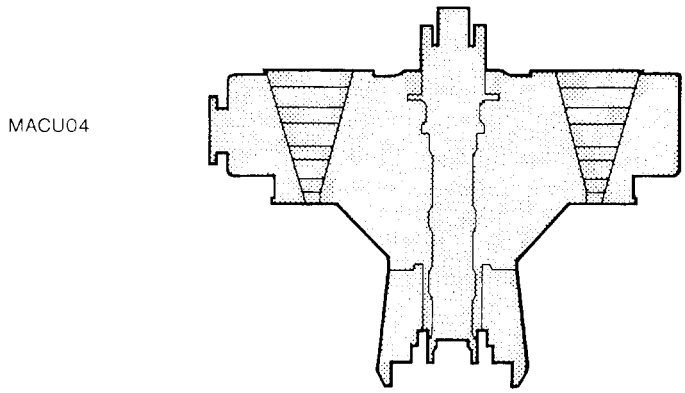


FIG. 3—SM1A GTCU IN POSITION FOR MAINTENANCE ASSEMBLY EXCHANGE

The exchange of MACUs is carried out with the GTCU mounted vertically in the 'nose down' position, as seen in FIG. 3, and the MACUs are lifted away from the 'tail' of the engine, either singly or in groups, to give access to the defective MACU(s) which are to be replaced. Two examples of MAX are shown in FIGS. 4 and 5, but of course it is possible to change more than one MACU at a time should a defect require it.



OPERATIONS

1 Turn the GTCU from the horizontal to the vertical 'nose down' position

2 Remove MACU05 (Exhaust Annulus)

3 Release the Compressor/Turbine shaft coupling nuts

4 Separate MACU04 from MACU03

5 Change MACU04

6 Reverse the above procedure to reassemble the GTCU

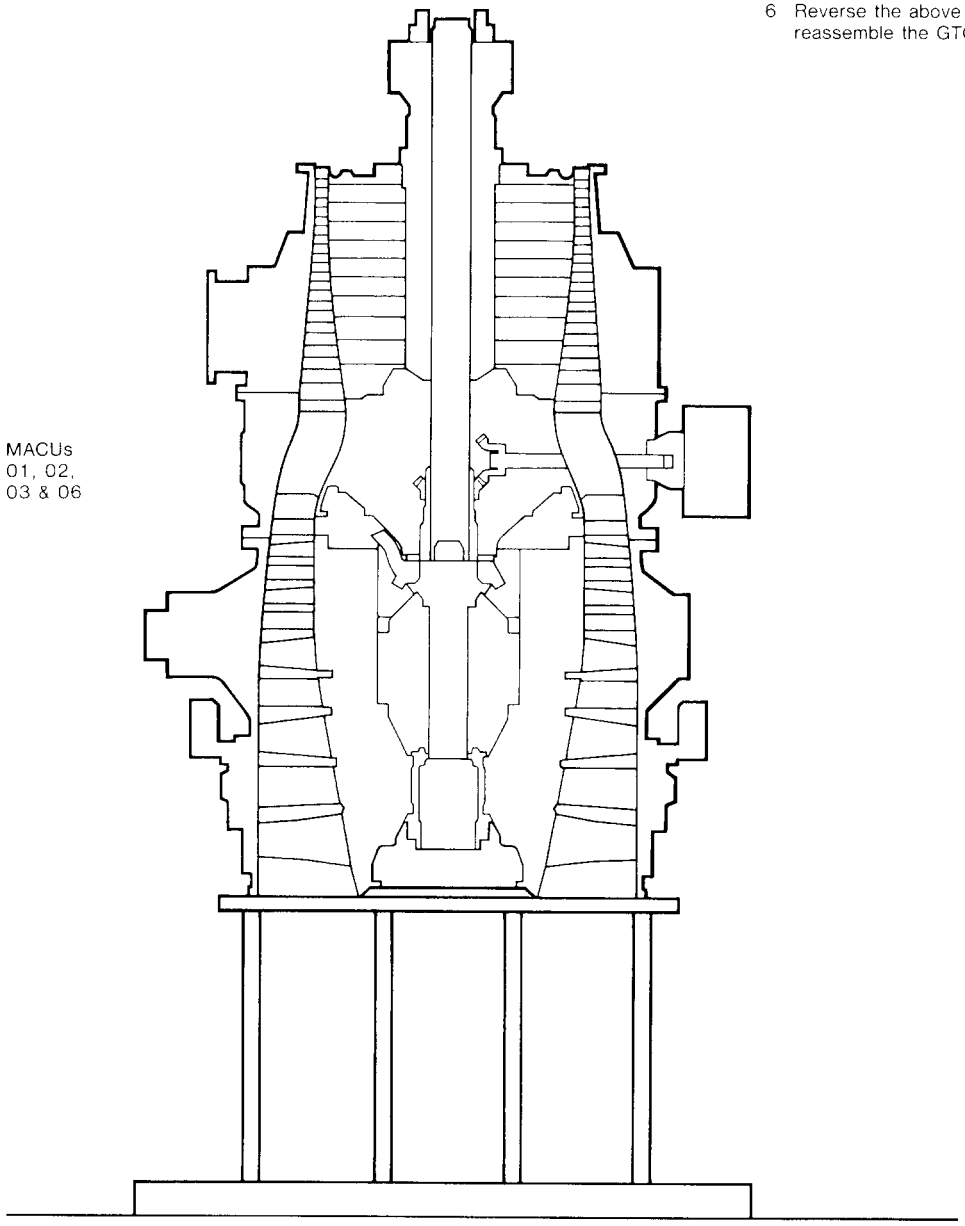
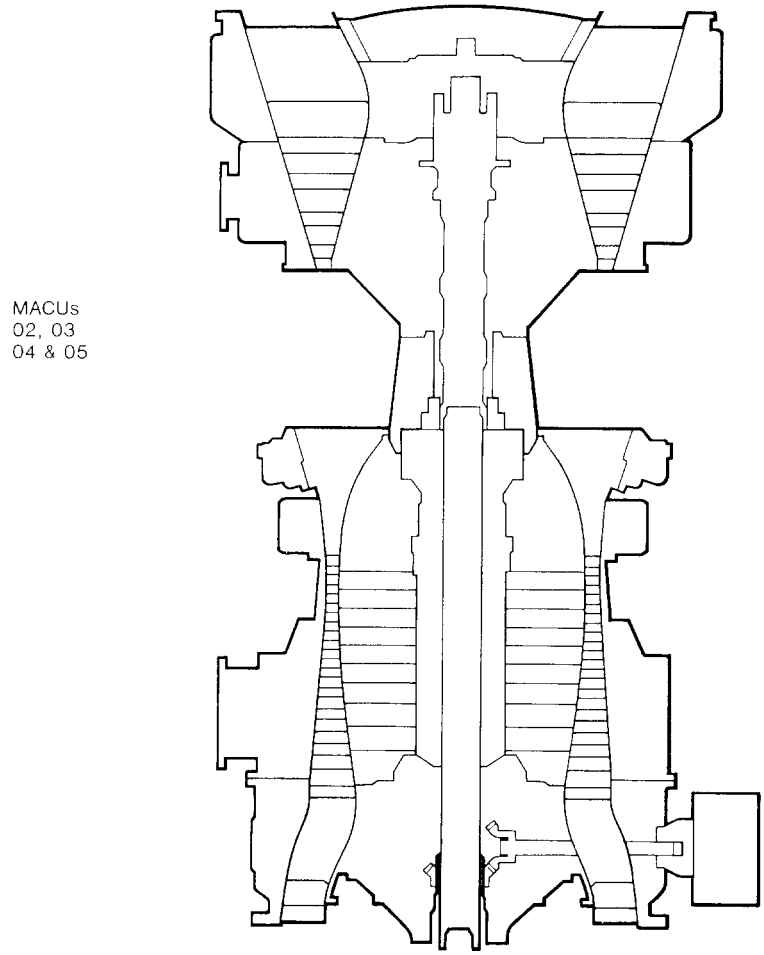


FIG. 4—MAINTENANCE ASSEMBLY EXCHANGE—MACU04



MACUs
02, 03
04 & 05

OPERATIONS

1 Fit the necessary tooling ready to uncouple the HP Compressor from the LP Compressor

2 Turn the GTCU from the horizontal to the vertical 'nose down' position

3 Remove MACU06 (High Speed Gearbox)

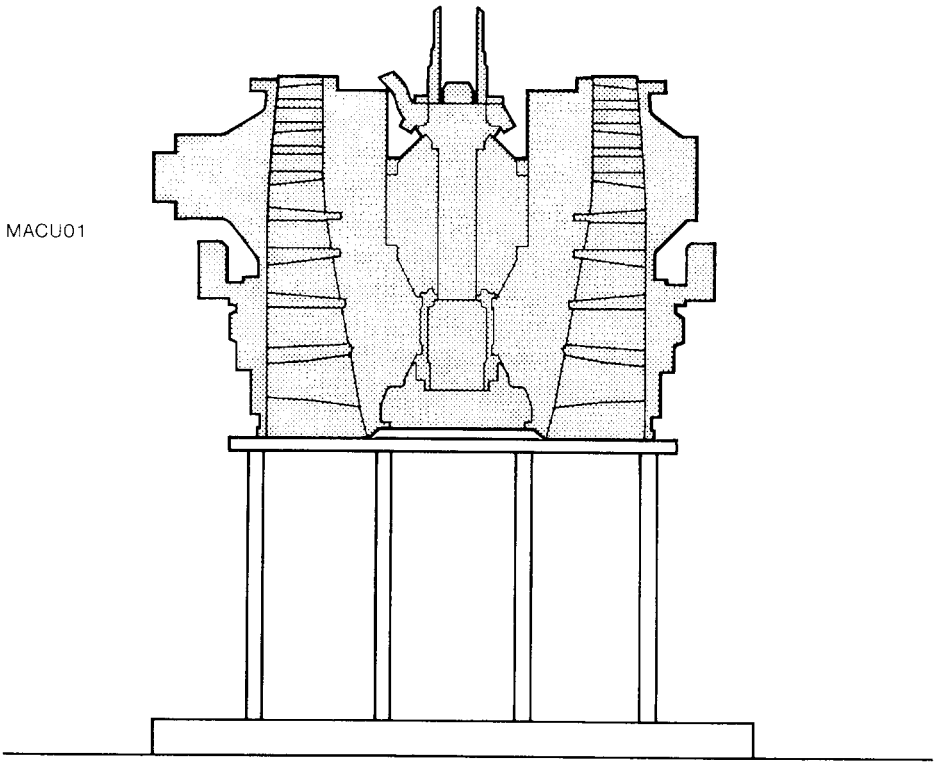
4 Disconnect the attaching parts

5 Uncouple the HP Compressor from the LP Compressor

6 Hoist MACUs 02, 03, 04 and 05 clear of MACU01

7 Change MACU01

8 Reverse the above procedure to reassemble the GTCU



MACU01

FIG. 5—MAINTENANCE ASSEMBLY EXCHANGE—MACU01

It can readily be appreciated that the time required to induct, strip, repair and dispatch a GTCU, termed the Turn Round Time or TRT, will be greatly reduced using the MAX procedure, and the (relatively) lengthy process of repair or overhaul is restricted to the rejected MACU(s), whilst the serviceable GTCU can be either issued to the fleet or consigned to a store. The target TRT for repair of a Spey SM1A by MAX is currently four weeks and that to overhaul a given MACU by a strip/clean/inspect/salvage/rebuild operation is ten weeks. These times compare very favourably with the target time to overhaul an Olympus of 26 weeks and it is obvious therefore that the associated non-availability of a given SM1A through overhaul is in the region of one sixth that of an Olympus for a similar defect.

GTCU Removals

Since January 1986 there has been a total of 15 SM1A removals from ships, as shown in TABLE I.

TABLE I—*Spey SM1A removals*

Date	*Engine No.*	*Ship*	*Reason for Removal*
May 87	1903002	*Brave*	FOD
May 87	1903008	*Brave*	FOD
Oct 87	1903033	*Brave*	FOD
Nov 87	1903031	*Brave*	FOD
Nov 87	1903026	*Cornwall*	FOD
Nov 87	1903029	*Cornwall*	FOD
Mar 88	1903064	*Cumberland*	suspected crack
Dec 88	1903056	*Norfolk*	FOD
Jun 89	1903018	*Cornwall*	FOD
Nov 89	1903028	*Brave*	turbine erosion
Nov 89	1903035	*Brave*	turbine erosion
Jan 90	1903019	*Cornwall*	turbine erosion
Feb 90	1903063	*Cumberland*	turbine erosion
Jun 90	1903078	*Argyll*	flooded with lub oil
Apr 91	1903007	*Cumberland*	turbine erosion

FOD: Foreign Object Damage

Compressor Problems

TABLE 1 shows a high incidence of Foreign Object Damage (FOD) to the SM1A in the early years. With the exception of HMS *Norfolk*, whose GTCU (056) suffered a slight nick to an HP Compressor blade, all the FOD damage was as a result of debris, particularly what appeared to be ferrous shotblasting material, remaining undetected in the engine downtakes of new ships, despite rigorous inspection and acceptance routines. In the case of HMS *Brave* the damage to her original pair of engines (002 & 008) went unnoticed until it was revealed during an investigation into compressor surge problems being experienced by the ship. The subsequent rejection of her replacement engines (033 and 031) due to recurring FOD damage demonstrated that, regardless of the intensive inspection and cleaning carried out after discovery of the original damage, the offending debris was still present and it was tracked down concealed in the upper regions of the downtakes from where it was being progressively leached into the engines. This problem was solved ultimately but it required the downtakes to be stripped to facilitate satisfactory deep cleaning. A survey of some other RN vessels revealed similar damage to HMS *Cornwall*'s SM1As, leading to their rejection after relatively few hours running. (It is worth mentioning at this point that this particular problem was not restricted to the SM1A and some damage occurred to Olympus and Tyne GTCUs under similar circumstances).

However, the damaged GTCUs were successfully restored to serviceable condition by MACU exchange, mainly of the HP Compressor since it was an interesting feature of this particular FOD saga that the LP Compressors escaped largely unscathed, whilst the HP Compressors appeared to bear the brunt of the damage, especially downstream of the sixth stage blading. FIG. 6 shows a typical example of the type of damage seen in the affected engines. Although the Overhaul Facility successfully demonstrated its ability to repair the affected engines, the unexpected influx of one particular type of damage caused a temporary shortage of compressor blades. This situation served to highlight a further benefit of MAX in that, although the repair of some compressor MACUs was held up as a result of the shortage, the parent GTCUs were unaffected since they were repaired through use of available stocks of spare/repaired MACUs and thus they remained available for issue to the fleet.

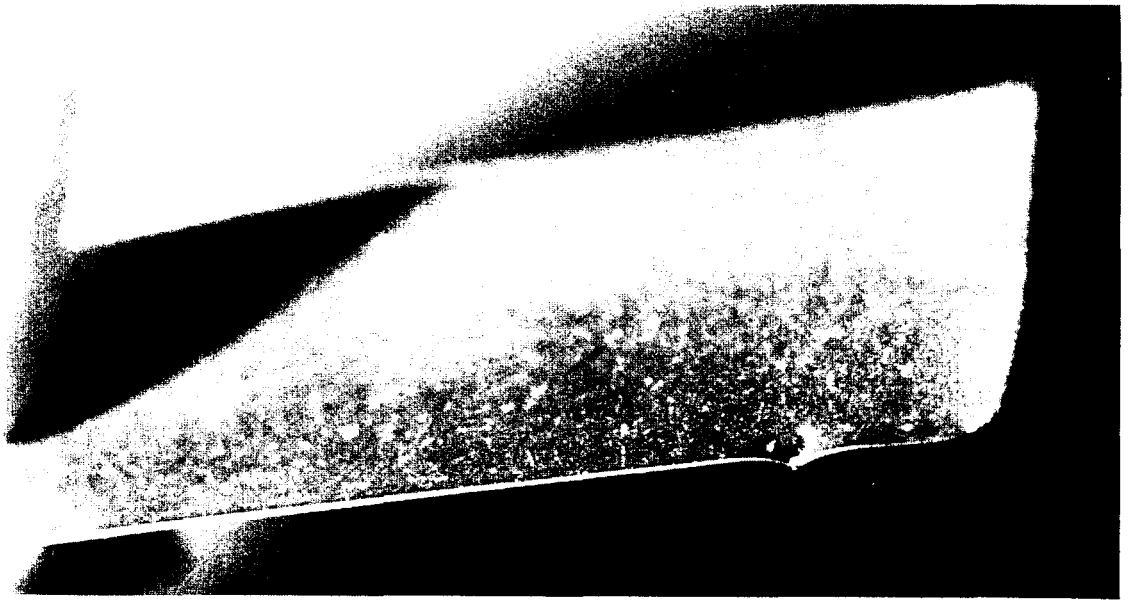


FIG. 6—SM1A HP COMPRESSOR BLADE FOD DAMAGE—SEVENTH STAGE

Turbine Troubles

Further study of TABLE I shows that several GTCU removals are annotated as being due to Turbine Erosion. This major problem first came to light during the endurance testing of the SM1A at RAE Pyestock[2] and it was subsequently also seen in engines removed from the fleet such as the two GTCUs taken from HMS *Brave* in November 1989 (028 & 035) when her SM1As were replaced with SM1Cs for the SM1C Fleet Trial. The turbine damage (FIG. 7) is caused by carbon build up in the combustionware which periodically breaks away and passes through the turbine stages causing erosion as it does so, primarily to the first row of Nozzle Guide Vanes and Turbine Blades. This created a number of GTCU rejections after approximately 1200–1500 hours of running compared with the planned life of an SM1A of 3000 hours running before overhaul.

Once again, the MAX process restored the affected GTCUs to serviceable condition whilst the damaged Turbine MACUs remained at Rolls-Royce for repair. Unfortunately though, for the second time in the relatively short career of the SM1A to date, an unexpected influx of one particular form of damage created a material shortage on the Overhaul Line, but again the MAX concept ensured that the parent GTCUs were not withheld from service whilst the damaged MACUs awaited parts, turbine blading having a typical lead time of eighteen months to two years.

The problem of turbine erosion itself has been addressed and solved through improvements to the combustionware, the details of which are outside the scope of this article, except to say that a Modification (SPG 681) is being introduced into the fleet as fast as material becomes available. In the interim, a revised operating profile and a series of regular, detailed hot end inspections has allowed a number of affected engines to be 'run on' and hence the rejection of GTCUs has eased. The most recent SM1A removal due to turbine erosion was after approximately 2400 hours running.

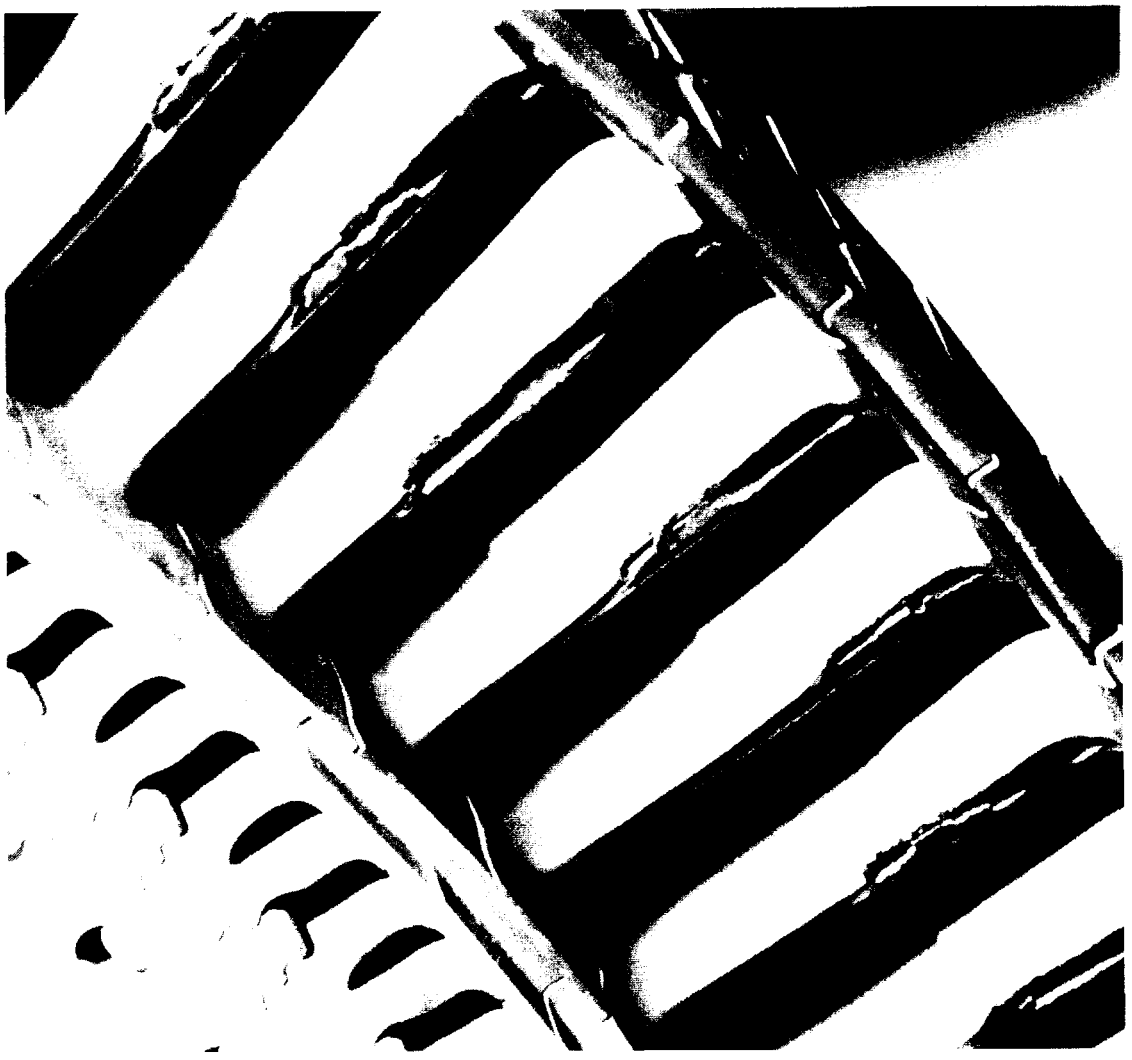


FIG. 7—TYPICAL SM1A TURBINE BLADE LEADING EDGE EROSION—HP FIRST STAGE

Other Problems

Foreign Object Damage and Turbine Erosion aside, there have been only two other GTCU removals to date. The first was one of HMS *Cumberland*'s original GTCUs which was suspected of having a blading crack although this was subsequently not proven. The other was one of HMS *Argyll*'s original pair of engines which was flooded with lubricating oil shortly after installation and which required a full strip down to be carried out for cleaning purposes.

Gaining Experience

It could be said that the early years of Spey operation in the Royal Navy have been rather unhappy ones with two major unforeseen sources of GTCU damage. This, in many ways, would be an unfair criticism since, by definition, many of the decisions regarding rejection of SM1A GTCUs have had to be made from positions of limited knowledge as a result of the relatively low number of running hours amassed to date. As knowledge has been built up, particularly in the area of blade damage acceptance criteria, it has been possible to retain GTCUs in ships which earlier might have been declared as being beyond help and subsequently rejected for repair by MAX. Such a learning process is a normal part of the introduction of any new gas turbine and in this regard the Marine Spey SM1A is no exception.

The Future

The MACU exchange concept is still a new one in the marine gas turbine world but it has already proved to be successful in light of RN experience and as a result the Rolls-Royce Spey SM1C now being purchased is also a modular engine which will enjoy the benefits of MACU exchange when it enters service fully with Type 23 10.

However, the MACU concept is not without its problems. As with all other marine gas turbines in the Royal Navy, the Gas Turbine Allocation Authority (GTAA) will manage the stocks of SM1A GTCUs and MACUs as well as managing their overhaul and repair. The RN SM1A fleet, as previously described, will ultimately comprise twelve ships and, through the Memorandum of Understanding with the Royal Netherlands Navy relating to SM1A support, GTAA will have to manage somewhere in the region of 46 SM1A GTCUs including support spares. Therefore, taking into account the support stocks of spare MACUs, the management task escalates to keeping track of some three hundred separate MACUs, each with the ability to be either part of a GTCU or to be on the shelf as a spare, and in effect each can be considered as a separate 'mini-GTCU' with an individual life history. Since the serial number of an SM1A GTCU is only carried by MACU02, 'tracking' of individual MACUs by individual serial number will be essential in keeping abreast of their respective life consumption (hours run) and hence life remaining before individual overhaul falls due. Additionally it will allow their individual Modification states to be logged. It is also worth noting that the six MACUs have different life expectancies ranging from, at present, 3000 hours for MACU04 (Turbine) to 20 000 hours for MACU02 (Intermediate Casing). Thus, when a 'set' of six MACUs reaches the Overhaul Life of the GTCU (3000 hours) only the Turbine will require to be exchanged, given that all the MACUs were at zero life at the outset. As SM1A operating experience accumulates it can be seen that the range of lives remaining on individual MACUs will increase and GTCUs may need to be constructed using a type of mix and match approach to allocate MACUs, some of which will be 'part life expired', to best advantage as the opportunities arise (i.e. MAX). To this end, GTAA is investigating the introduction of a computer-based system to handle the task of managing MACUs and the GTCUs they may be part of ('conventional' GTCUs are managed manually) since in the future not only will the numbers of MACUs increase but so will the number of different types. This is because although the SM1C GTCU consists of only five MACUs, none of them are interchangeable with any of the six SM1A units. With the prospect that the population of Spey-related MACUs could conceivably peak at over 400 units, the need for something to replace the time-honoured filing cabinet may become overwhelming.

Conclusion

The MACU concept, now five years young in the Royal Navy, has proved to be a flexible and speedy method of repairing gas turbines which can offer real advantages in the reduction of Turn Round Times with the prospect of increased availability of serviceable engines to the fleet. Additionally, the reduction of engine non-availability time through repair can result in a reduction in the number of spare GTCUs required in support of a given fleet, with an attendant reduction in support costs.

References

1. Parry, R. W. and Doxsey, R. A.: Spey SM1C gas turbines in HMS 'Brave'; *Journal of Naval Engineering*, vol. 32, no. 2, June 1990, pp. 302–306.
2. Cartwright, R. A. and Lambert, P. B.: SM1A marine gas turbine evaluation at Pyestock; *Journal of Naval Engineering*, vol. 32, no. 2, June 1990, pp. 287–302.