SPEY SM1C GAS TURBINE

THE FIRST YEAR (1000 HOURS) IN HMS 'BRAVE'

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ABSTRACT

The Type 22 Batch II frigate HMS *Brave* is the subject of a trial of the first two Rolls-Royce Spey SM1C gas turbines, under the auspices of Fleet Trial 93/88. The article gives a report on the events of interest over the first year/1000 hours of operation of the new engines, including operational performance, inspection results, defects found and design solutions in prospect. The future Royal Naval applications of the SM1C gas turbine are briefly discussed together with potential sales prospects to other customers.

Introduction

Spey SM1C propulsion units rated at 18 MW were installed in HMS *Brave* as Fleet Trial 93/88 during the period November 1989 to January 1990, as described in a previous *Journal* article[1]. Since that time each engine has been run for over 1000 hours, and the purpose of this article is to describe their in service performance.

Trials

Initial sea trials, overseen by the Machinery Trials Unit, took place during late January and early February 1990. Poor weather conditions precluded completion of all serials, but sufficient information was obtained to enable the engines to be declared satisfactory for operational use. Minor adjustments to the MECCA fuel schedule were found to be necessary to optimize propulsion plant performance, but this did not affect the attainment of full engine power. A simplified top power setting procedure, used to adjust the fuel system controller for maximum power with the engine shut down, was found to be a significant improvement over that previously used for the Spey SM1A, and has been subsequently adopted for that engine.

Formal trials, including manoeuvring, engine change-over and steady state serials both ahead and astern, were progressed by ship's staff through the spring and early summer with fully satisfactory results. Upgraded gasket material for the special service air system pipework to withstand the higher pressures generated by the Spey SM1C was fitted in mid 1990, and the system tested and operated up to maximum engine power with no difficulty. Throughout the year the gathering of data for the analysis of engine usage and condition was an important part of the Fleet Trial. The information obtained during that period is discussed further below.

Operating Profiles and Performance

Over 1000 running hours per engine had been amassed by mid November 1990, and the pattern of accumulation is shown in FIG. 1. The Speys had been run in preference to the Tyne engines when operational circumstances permitted, and thus experience of Spey SM1C operation over a wide power range was achieved. The distribution of power with time is shown in FIG. 2, represented as percentages of time spent in particular power bands; the cumulative percentages are also shown. The power bands, which cover the entire power range, are based on a propeller law to give a more representative view of operational engine usage than would have been possible with linear power intervals.

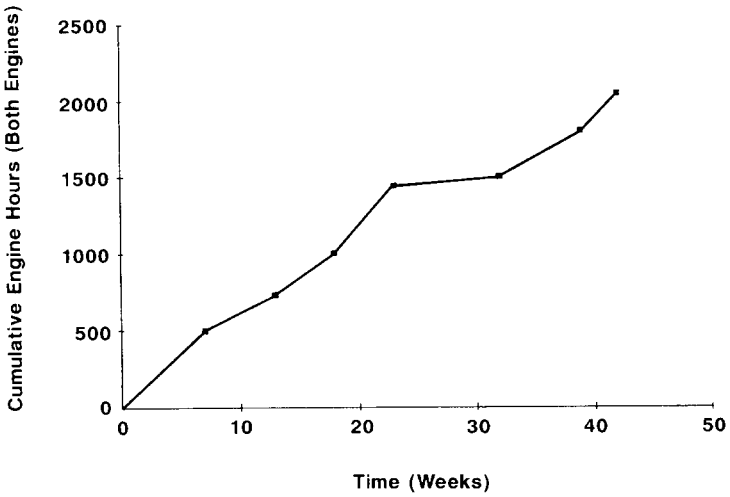

FIG. 1—ACCUMULATION OF SPEY SM1C EXPERIENCE

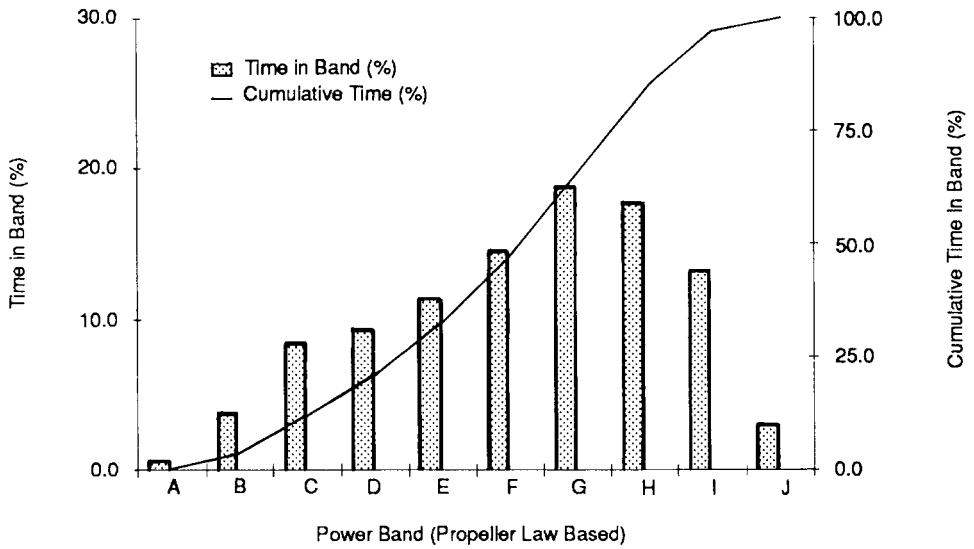

FIG. 2—SPEY SM1C POWER USAGE DISTRIBUTION

A major achievement of the Spey SM1C has been its ability to provide comparable performance to the Olympus TM3B with much lower fuel consumption. FIG. 3 shows the variation of specific fuel consumption with shaft power for both engines, data for the Olympus having been taken from trials under similar conditions in another Type 22 Batch II B ship. It should

be remembered that the plots are based on installed shaft power, and that test bed data for the same machines would yield lower specific fuel consumptions. Whilst initially similar to the Olympus, a significant improvement in Spey fuel consumption occurs between 4 and 5 MW when the compressor HP7 bleed valve, incorporated to prevent compressor surge, closes. Thereafter a beneficial margin of 20–25% over the Olympus is obtained.

The marked effect of bleed valve closure of Spey SM1C efficiency became an important consideration in the operational use of the engines in HMS *Brave*. In particular the use of one Spey driving with the other shaft trailing was found to be a flexible and economic configuration.

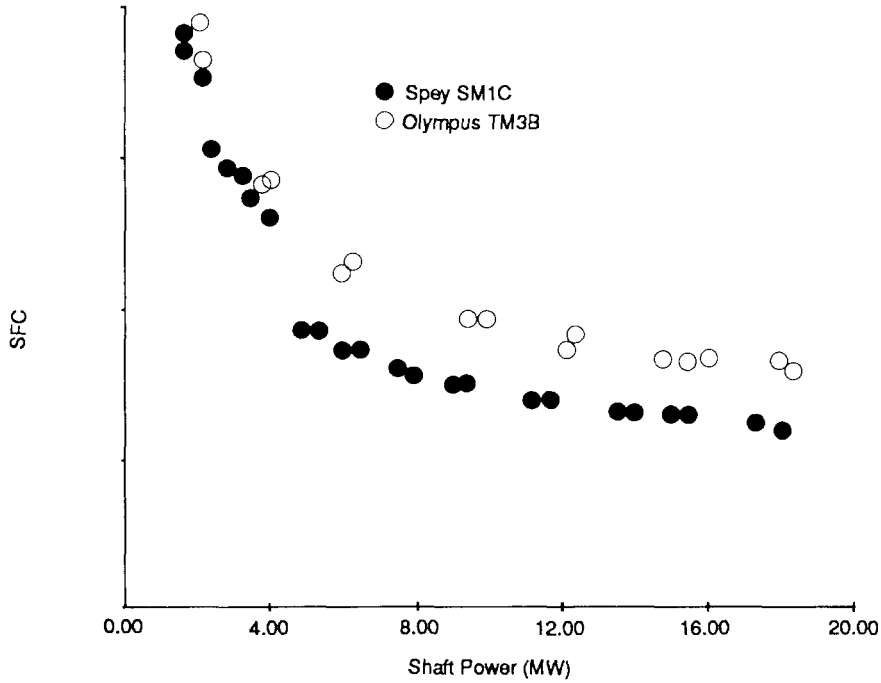

FIG. 3—SPECIFIC FUEL CONSUMPTION COMPARISON FOR SM1C AND OLYMPUS IN TYPE 22 BATCH II

Inspection Routine

In view of the technical interest in the progress and performance of the engines during the Fleet Trial it was decided to conduct joint Royal Navy/ Rolls-Royce internal inspections at approximately 250 running hour intervals. In practice these intervals were adjusted to fit in with convenient ship programme opportunities for inspections, taking into account any important factors emerging from previous inspections.

Over the first year of operation the inspections took place at approximately 230, 730, and 1030 hours, running hours being balanced equally between the engines.

Inspection Results

230 Hours—April 1990. Nothing untoward was found despite a very thorough two day internal endoscope inspection of both engines. There was evidence of carbon build up in the LPA (pilot burner) external drain pipe orifice but this had no effect on starting performance.

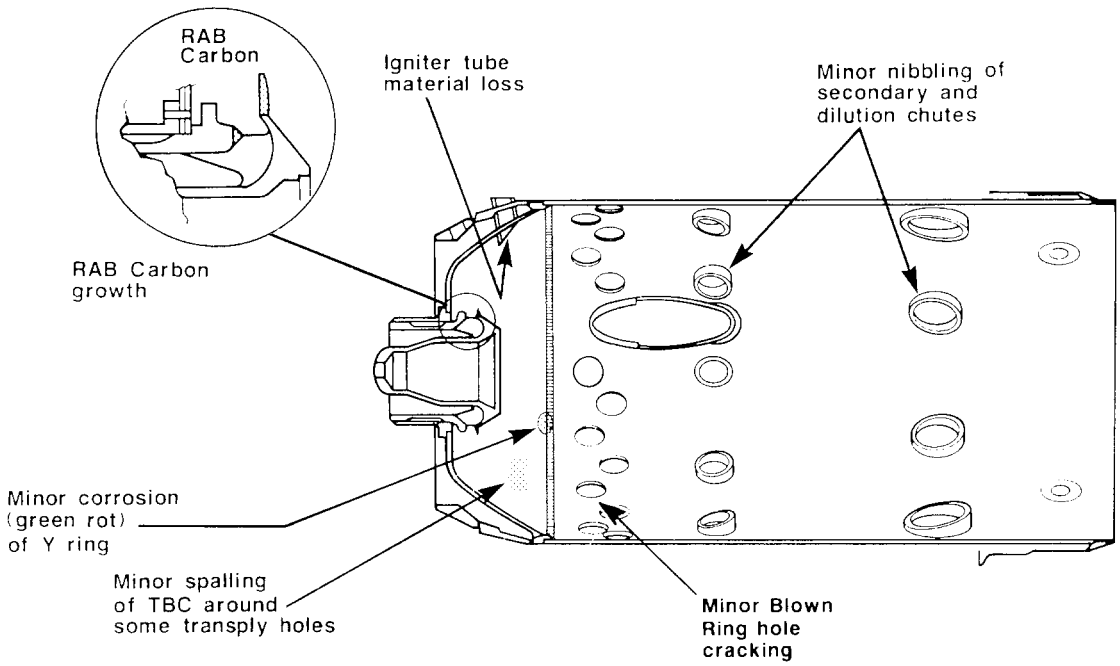

FIG. 4—COMBUSTION LINERS CONDITION AFTER 730 HOURS

FIG. 5—COMBUSTION LINER BARREL AFTER 730 HOURS

FIG. 6—IGNITER TIP BURNING AFTER 730 HOURS

730 Hours—July 1990 (Starts, 195 port, 184 stbd). The inspection was delayed until the ship's return from a ten week deployment. Again nothing of concern was observed. The following minor points, typical for the running hours accumulated, were noted:

(*a*) Combustion chambers: two small spots of corrosion (green rot) were evident on the 'Y' ring caused by the high sulphur fuel; there was also minor blown ring hole cracking together with secondary and dilution hole nibbling. There was evidence of a frill of carbon around the Reflex Airspray Burners (RAB) and one igniter tube had lost a small amount of material at the innermost end. (FIGS. 4 and 5).

(*b*) Igniters: one igniter on the port engine had suffered overheating at the tip and was replaced as a precaution (FIG. 6).

(*c*) LPA System: drain pipes on both engines and one LPA pigtail pipe was blocked by carbon (FIGS. 7 and 8).

FIG. 7—LPA DRAIN CARBON BLOCKAGE AFTER 730 HOURS

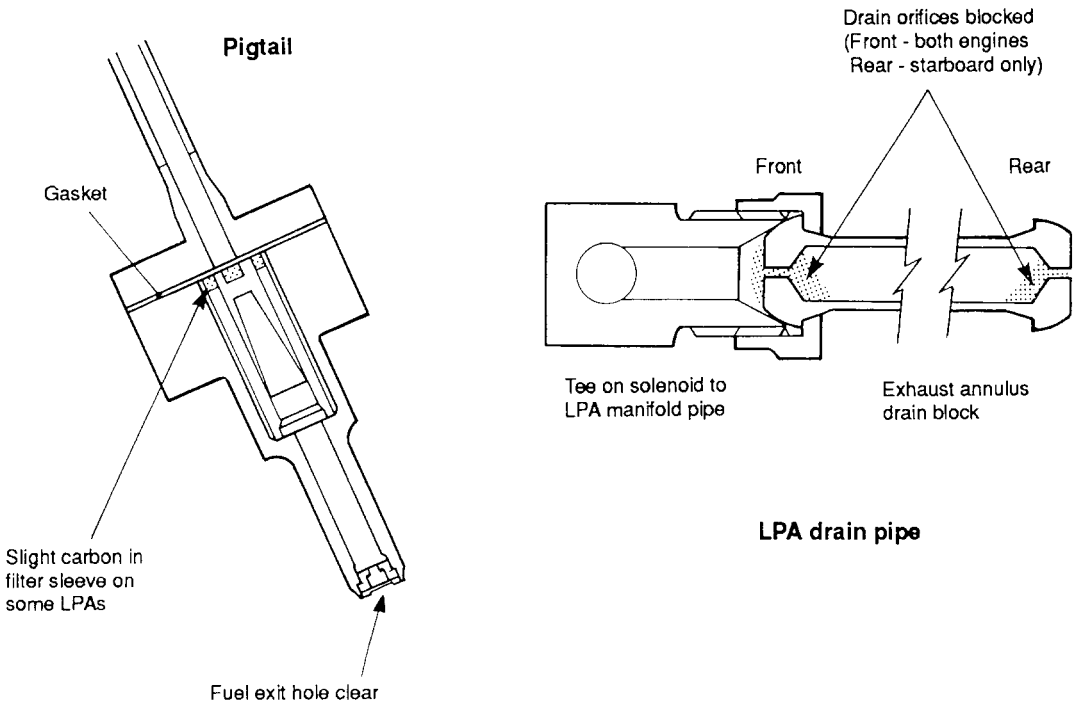

FIG. 8—LPA SYSTEM CARBON DEPOSITS AFTER 730 HOURS

(*d*) Turbine Blading: careful examination revealed no sign of degradation.

(*e*) Compressor Blading: clean and in very good condition. (Note: HMS *Brave* has used only aqueous-based compressor washing fluids since the installation of the SM1Cs).

1030 hours—Nov 1990 (Starts, 268 port, 244 stbd). A similar picture to the previous inspection emerged with further spread of the small areas of combustion chamber corrosion, reoccurence of the LPA system drain blockage and another igniter suffering from overheating. The condition of the compressors and turbines remained as before, i.e. in excellent shape. (FIGS. 9 to 12). Concern was felt about the integrity of the starboard engine HP7 bleed valve bellows and it was replaced. Subsequent inspection of the damaged bellows showed it had experienced mechanical damage either on original fitting or from an external source whilst in service. A check of the port engine bellows gave it a clean bill of health for continued use.

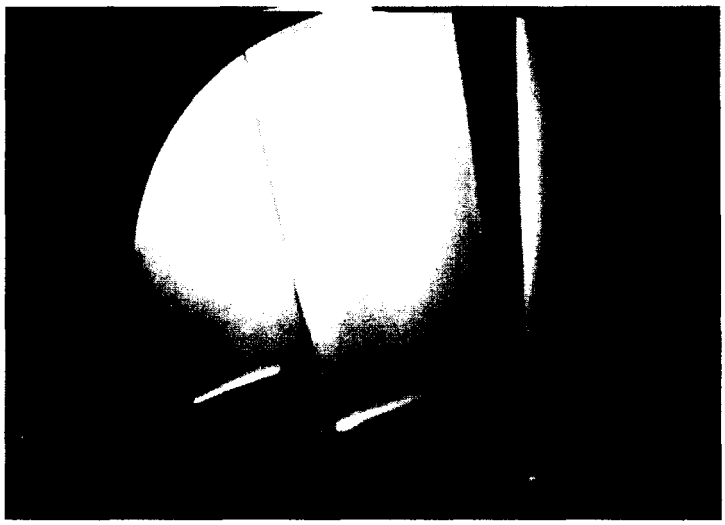

FIG. 9—HP1 COMPRESSOR BLADES AFTER 1030 HOURS

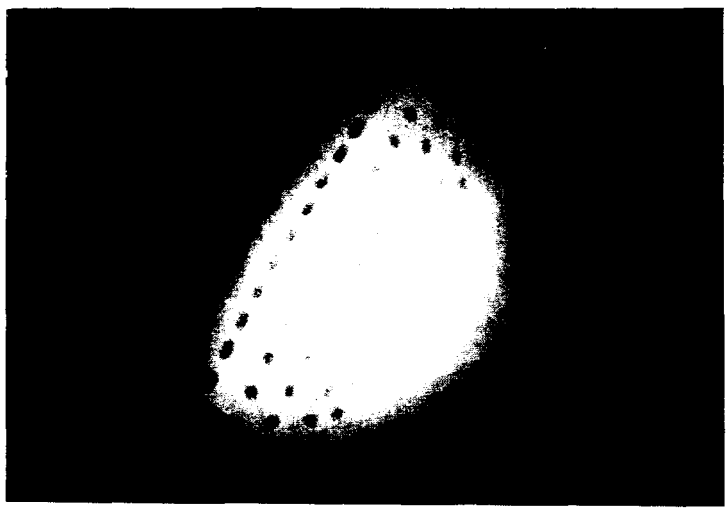

FIG. 10—HP1 NOZZLE GUIDE VANE LEADING EDGE AFTER 1030 HOURS

Defects and Design Solutions

There were remarkably few problems or defects during the first year of operation of what amounted to a major engine redesign at sea for the first time. Those defects that have occurred can be classified as minor and with design solutions well in hand:

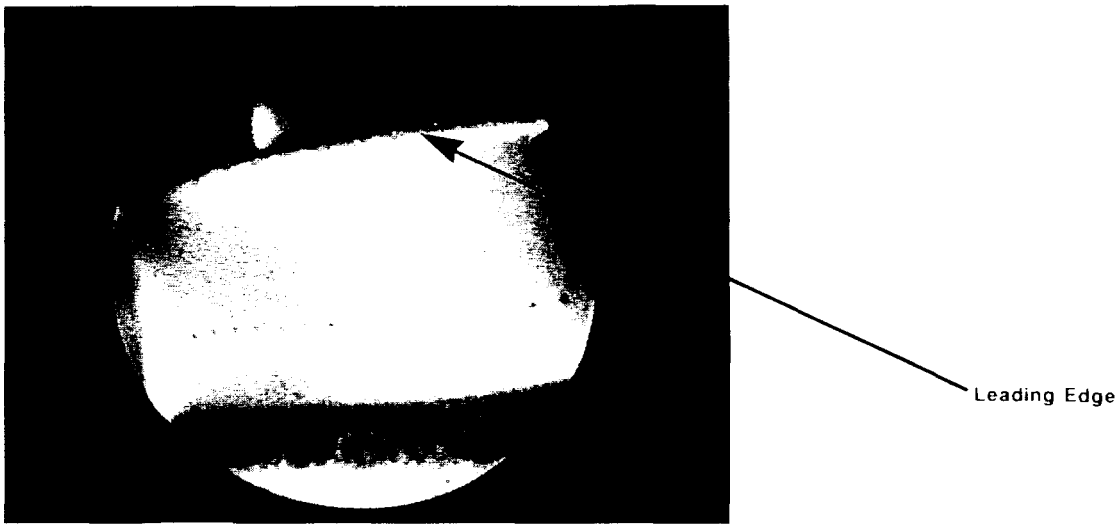

FIG. 11—HP1 TURBINE ROTOR BLADE AFTER 1030 HOURS

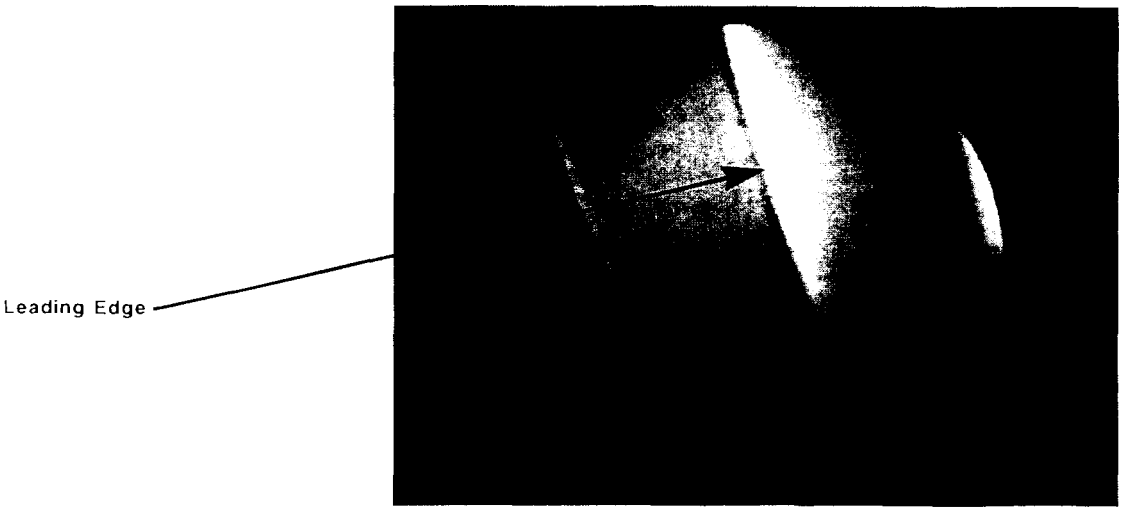

FIG. 12—HP2 TURBINE ROTOR BLADE AFTER 1030 HOURS

(*a*) *LPA drain blockage.* The repeated carbon blockage of the LPA drain pipe is caused by overheating of fuel lying in the drain pipe system. Repositioning the drain connexion and rescheduling a solenoid valve will prevent the build-up of fuel in this area and hence the source of the carbon. To date this problem has yet to affect starting performance but could if allowed to persist. (FIG. 13).

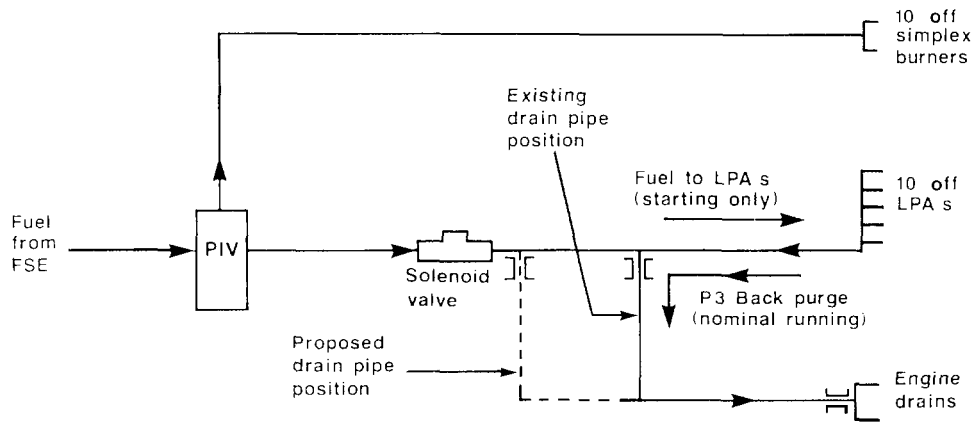

FIG. 13—LPA PURGE SYSTEM—REVISED DRAIN PIPE POSITION

(*b*) *Igniter Overheating*. Under certain operating conditions the tip of the igniters in the SM1C are exposed to temperatures above that considered acceptable for long life. Development tests have shown that redesign of the igniter tube dramatically reduces the tip temperature and, at the same time, gives relative insensitivity to igniter immersion depth (FIG. 14). So far two igniters have been replaced in HMS *Brave*, one of the two on each engine, neither failure affected starting performance, thereby unintentionally proving the single igniter starting capability of the SM1C.

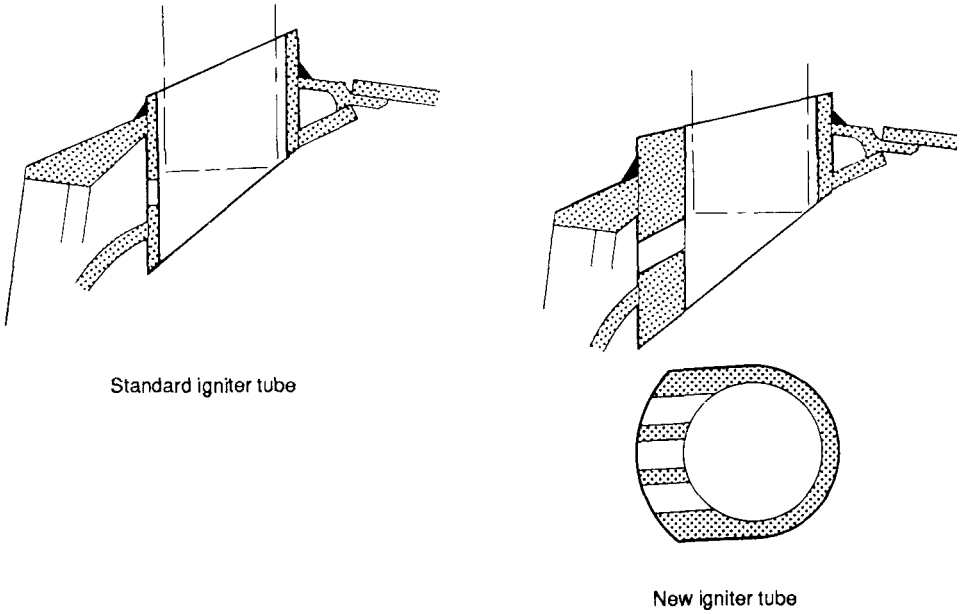

FIG. 14—SM1C COMBUSTION—IGNITER TIP DETERIORATION AND IGNITER TUBE MODIFICATION

(*c*) *RAB Carbon Frill*. Given the history of the serious effects of carbon erosion on turbine blades in the early SM1A engines, any carbon generated in the combuster system is seen as undesirable. Minor changes to the RAB centre body geometry and cooling are being made to eliminate this carbon frill. It should be noted that the type and quantity of carbon seen in the SM1C is of little consequence, as borne out by the excellent condition of the turbine blade leading edges.

(*d*) *Power Turbine Speed Probe*. One unscheduled shut down of the starboard engine was caused when oil leaked into the power turbine speed probe junction box. The defect was traced to a leaky gland on the power turbine centre body allowing oil to track down the conduit and fill the adjacent junction box causing a power turbine overspeed alarm. This was considered to be an assembly shortfall related to the compound-filled gland rather than a design deficiency. (FIG. 15).

Reliability

The SM1Cs in HMS *Brave* have provided outstanding reliability since installation, with only one failed start out of a total of 512 starts to date plus one unscheduled shut-down (power turbine probe oil leak). Magnetic chip detectors have remained clear, vibration levels normal and oil consumption commendably low at between 0.2 and 0.35 litres per hour.

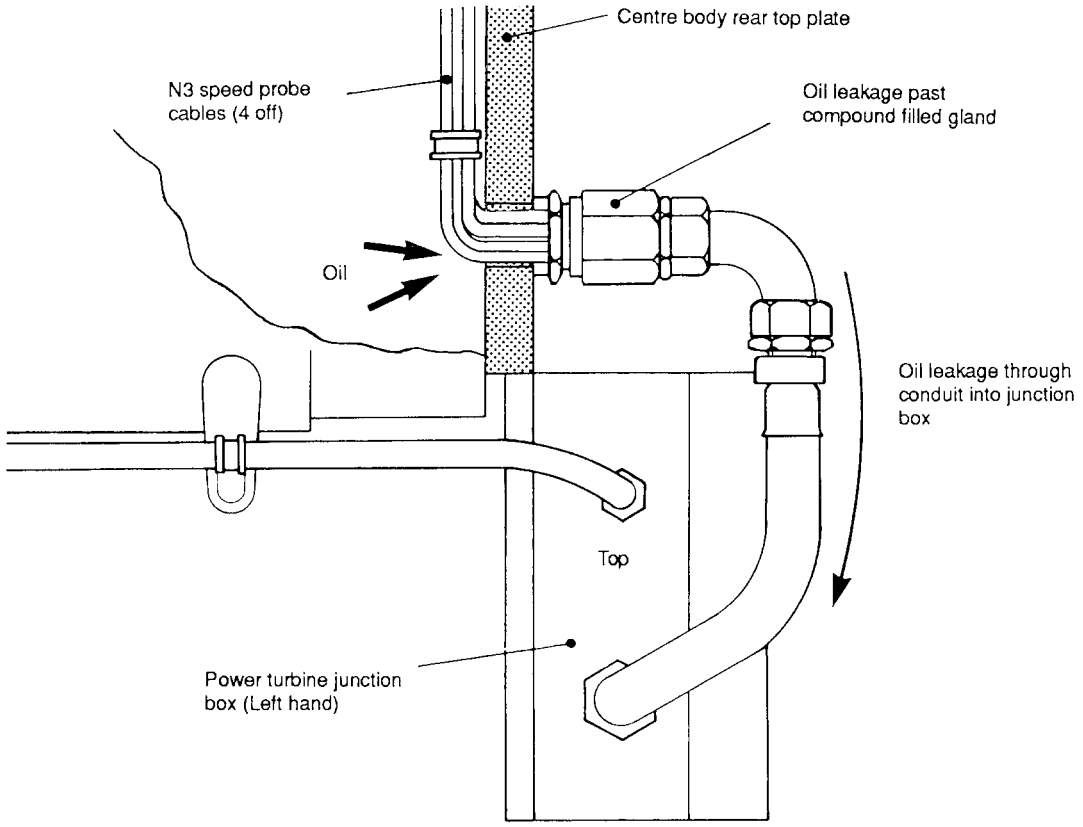

FIG. 15—OIL LEAKAGE INTO POWER TURBINE JUNCTION BOX, HMS 'BRAVE'

The Future

It is intended that the engines in HMS *Brave* will be retained in service at least until the planned RP1 in 1992, when a detailed inspection will be carried out. Concurrently, a 3000 hour endurance trial is being conducted at RAE Pyestock to give additional confidence in the SM1C's life capability, together with a range of related minor trials, such as rescheduling of the HP7 bleed valve to operate at a lower power and thus further improve part-load efficiency.

The Spey SM1C was accepted into the naval programme in mid 1990 and the first RN production order to purchase engines and support spares for Type 23 ships 10 and 11 was placed in October 1990. All Type 23 frigates from 23-10 onwards will be SM1C powered, albeit at a 12.75 MW hot day rating for long life and hence reduced through-life costs. Looking further ahead, it is envisaged that future surface ship designs will utilize the engine at its full rating of 18 MW. It is encouraging that the SM1C is already attracting considerable interest from foreign navies as a possible power plant for new destroyer and frigate ship projects, and also from potential commercial customers seeking to compete with the Channel tunnel by the use of fast ferries, for which the SM1C is an ideal contender.

Conclusions

In summary, the first 1000 hours of Spey SM1C operation in HMS *Brave* have proved more successful than even the most optimistic viewpoint could have anticipated. Reliable, flexible and efficient, there is every expectation of continuing success.

Reference

1. Parry, R. W. and Doxsey, R. A.: Spey engines in HMS 'Brave'; *Journal of Naval Engineering*. vol. 32, no. 2, June 1990, pp. 302-306.