MARINE SPEY '86 UPDATE

BY

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Overview

All major activities associated with introducing the Marine Spey SM1A into service are now complete. The new 12·75 MW intermediate gas turbine entered Royal Naval service as a fuel-efficient boost engine in the Type 22 frigate, H.M.S. *Brave,* in February 1986 having successfully undergone acceptance trials. At the same time the engine has also entered service in the Japanese Navy but this time as a high duty cruise engine for the DDG. As with *Brave,* early experience there has been most encouraging with very few minor defects and high availability. Following an enhanced development programme fewer problems were expected from Spey than were encountered during the introduction of Tyne and Olympus. Although these are early days, it is pleasing to report that lessons have been learnt and the engine looks well set for the future.

The introduction of the engine into service is the culmination of a protracted and sometimes difficult development and test programme carried out at both Rolls-Royce, Ansty, and the Royal Aircraft Establishment at Pyestock. Originally the engine was envisaged in the context of a four Spey COGAG fit. Understandably the cancellation of the Type 43 and Type 44 programmes caused Spey development to lose momentum. As a rule of thumb, development expenditure is found to be largely dependent on calendar time. Given that the engine took nearer ten years to develop than the originally estimated five, a substantial real cost overrun was inevitable.

During marinization of the TF41 aero Spey engine the most intractable problem was developing the aero combustors (cans) to burn marine Dieso. It was found that the basic aero can was difficult to light and made smoke. The solution was a novel combustor which is characterized by a Reflex Air Burner (RAB). However, this can suffers corrosion problems and has a propensity to generate carbon which erodes the hot-end components. Further development work is in hand. In all other respects, testing so far indicates that the engine should be highly successful and reliable both in terms of niggling defects and premature removal rate.

Programme and Cost

It may be seen from TABLE I that the costs of marinizing an aero gas turbine are not insubstantial. The cost overrun is in part attributable to inflation and in part to the way that the Ministry has done business in the past whereby contracts were made on an 'Ascertained Cost' basis. This effectively meant that the contractor could continue spending until the aims of a development programme were achieved. This, combined with the MOD tradition of massaging the requirements, inevitably resulted in increased costs. Times have changed. Moie care is taken over specifications and contracts are now usually let on a Fixed or Maximum price basis against mandatory requirements.

TABLE I—*Spey SM1A Development Activities and Cost*

Activity	*Cost* £M
Feasibility, Project Definition and Full Development. The Development Cost Plan initially identified a spend of £10M at 1977 price levels to cover the cost of marinization of the TF41 aero Spey engine and to design and develop the engine Module. Design studies commenced in 1973 and hardware manufacture in 1977. By 1982 the cost had escalated to £23M (including a large element for inflation) and, although most of the programme was complete, some combustion problems remained. At about this time the Japanese Defence Agency (JDA) agreed to buy Spey SM1A on the basis that the Royal Navy would introduce the engine into service ahead of them, in the event in H.M.S. *Brave*	25·3
Life Extension. A test and development programme aimed at ensuring satisfactory introduction of the engine in *Brave*, scheduled for mid 1985	9·7
Endurance testing at RAE (Pyestock). A 3000 hours endurance test designed to underwrite the initial design Declared Overhaul Life	4·0
Shock Trial. A trial of a running engine installed in a module to assess engine survivability from underwater explosion	0·5
Total	37·5

Combustion

The RAB combustor (FIG. 1) is unique in that it has two regimes of combustion within the primary zone: a richer than stoichiometric primary reversal, and a weaker than stoichiometric zone where further air is added to complete the combustion process and burn out smoke. In the current production standard can carbon, which is formed on the RAB end cap and the bi-directional cooling ring, breaks off and impinges on the hot-end components. Of these the first row of turbine blades is the most affected. Whilst the first stage Nozzle Guide Vanes (NGVs) are less affected by erosion, corrosion has been observed as a result of 'hot spots' at the outlet from the turbine entry duct.

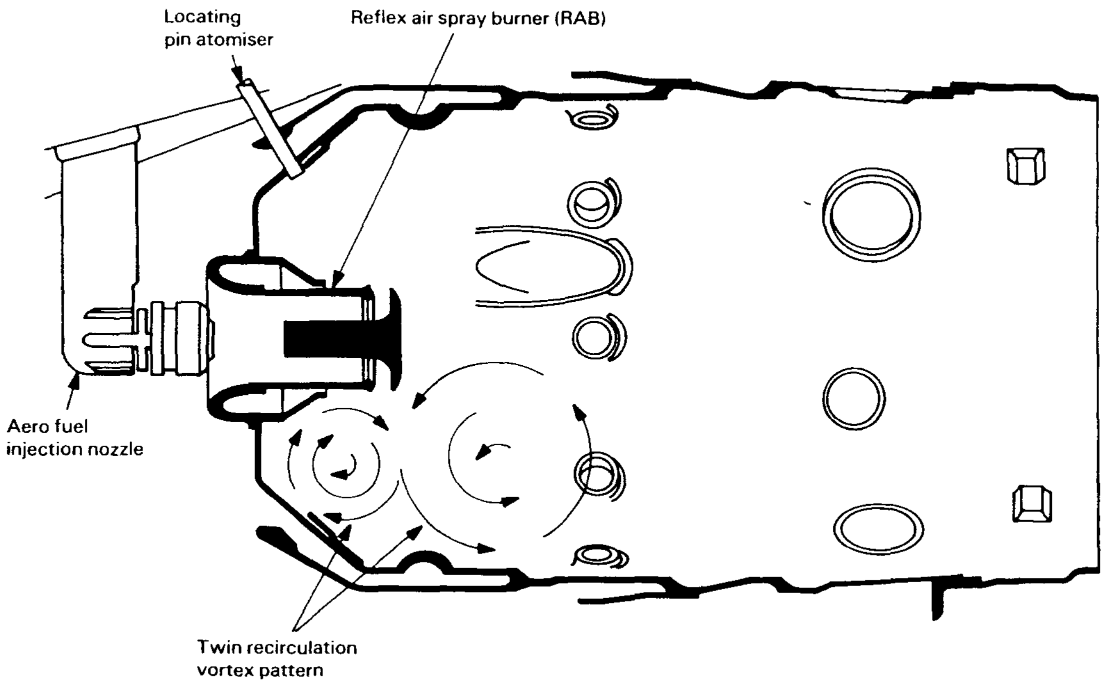

FIG. 1—REFLEX AIR BURNER (RAB) COMBUSTOR

The Company now proposes that we adopt an 'Improved RAB' combustor for SM1A which does away with the bi-directional cooling ring and has a reduced propensity to generate smoke and carbon. Early rig trials on the can are encouraging.

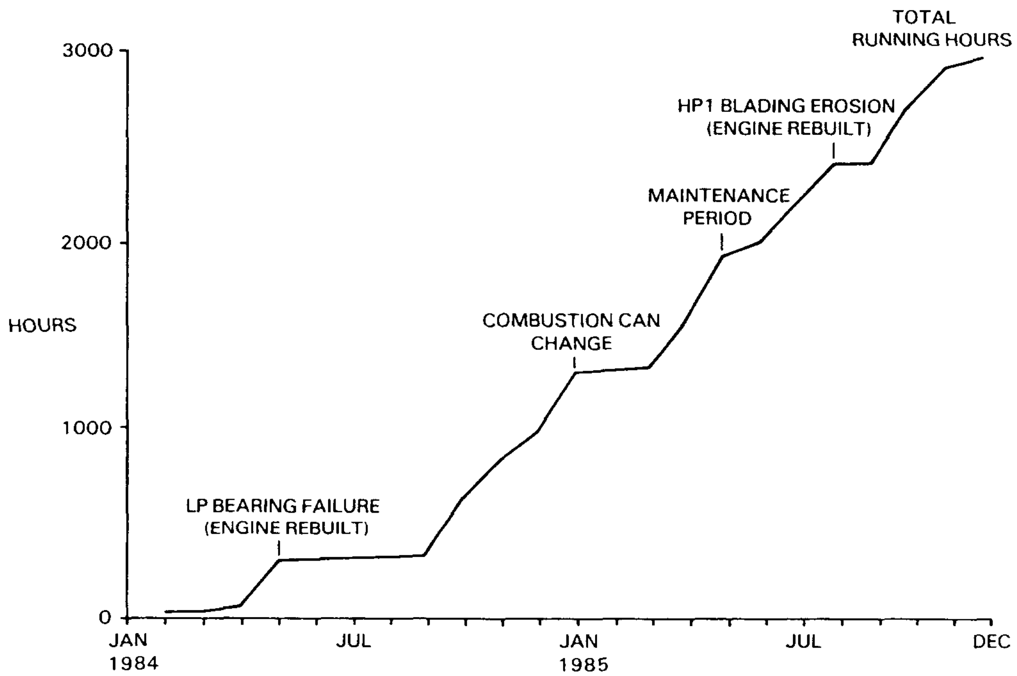

FIG. 2—SPEY SM1A 3000 HOUR ENDURANCE TRIAL

Endurance Testing at RAE Pyestock

The basis of the assertion above that the engine will be reliable and meet life targets is derived from endurance testing experience. The build-up of hours for the 3000 hour Pyestock endurance trial is shown in FIG. 2. It will be seen that there were three periods of unprogrammed downtime during the trials. These resulted from:

(*a*) *LP Bearing Failure.* After 350 hours, unacceptable vibration was recorded and the engine was removed for strip and inspection. It was found that the LP thrust bearing had failed as a result of light loading which caused skidding. (In order to prevent skidding it is necessary for the ball thrust bearing to have at least 500 lb. loading). It was found that there was a load reversal at about three quarters power. Further investigation showed that the simple expedient of cutting back on the trailing edge of the first stage NGVs increased the thrust load sufficiently to maintain an adequate positive loading throughout the power range. This is now an approved modification.

(*b*) *Combustion Chamber Exchange after 1330 Hours.* It was noticed after about 1300 hours running that the smoke levels were increasing. Endoscope inspection of the cans revealed that the bi-directional cooling ring had corroded to the extent that several lengths varying between one and two inches were missing. Subsequent investigation has shown that the corrosion mechanism (known as 'green rot' because of its colour) is heavily dependent on the sulphur content of the fuel. Fortunately Fleet levels of sulphur are falling. New fuel from the

North Sea fields has a sulphur content of around 0·1% compared to previous average Fleet levels of 0·7% so it is reasonable to expect a longer life in service.

(*c*) *HP1 Turbine Re-blading*. After 2300 hours the engine was removed in order to replace some of the HP1 Turbine blades which were holed, having eroded/corroded to the extent that they were not considered safe for further running. This is not as bad as it seems because the endurance engine had a 'rainbow' set of turbine blades with a number of different coatings. Fortunately blades with production coatings performed better than those which had to be removed. By the end of the trial the production LDC2E platinum aluminide coated blades were acceptable but would not have survived further prolonged endurance testing. Similarly the first stage NGVs were also heavily corroded (again with holes) and would not have survived long past the 3000 hour trial termination point.

It is generally accepted that the test conditions at Pyestock are more arduous than those experienced in service; certainly corrosion rates are known to be accelerated. On the positive side, apart from the three unprogrammed interruptions, the engine had remarkably few minor defects. The main points to be noted from Pyestock running are:

(*a*) The problems which caused engine removal should not result in similar early failures for engines now in service.

(*b*) The engine has demonstrated a 3000 hour life, as required by the Naval Staff Requirement.

Pyestock experience has been invaluable in providing a level of confidence for commissioning the new engine in *Brave* and for the early years of service.

18 MW SM1C Joint Venture Development

Readers of this *Journal*[1] will recall that Rolls-Royce proposed a Joint Venture (JV) uprating programme. The JV contract has now been signed and the Company are already in the second year of development with most of the design work complete. The new engine, designated SM1C, will be capable of 18 MW continuous operation with a life and reliability similar to SM1A. However, it will have a significantly longer life and higher reliability when operated at 12·75 MW. As discussed in the earlier article[1] it is the requirement for a longer life engine that has led to MOD participation in the development programme. Approval followed an Investment Appraisal (IA) which assessed the total cost of introducing SM1C and showed that for there was a nett present value saving arising from the longer life and better reliability.

For SM1C to remain viable it is essential that development costs are kept firmly under control. In negotiating the JV contract the Ministry has driven a hard bargain, negotiating a fixed price and including a contract condition which requires that development be continued until Rolls-Royce demonstrates a 5000 hour initial release life associated with a 12·75 MW continous rating. One of the challenges that will face a future Spey desk officer will be to agree with Rolls-Royce the satisfactory demonstration of this contract condition. There will clearly be interesting times ahead.

ICR Spey

Now that the 18 MW Spey programme is up and running, Rolls-Royce are vigorously pursuing the next variant. It has become apparent that the SM1C will make an ideal building block for an even more powerful and

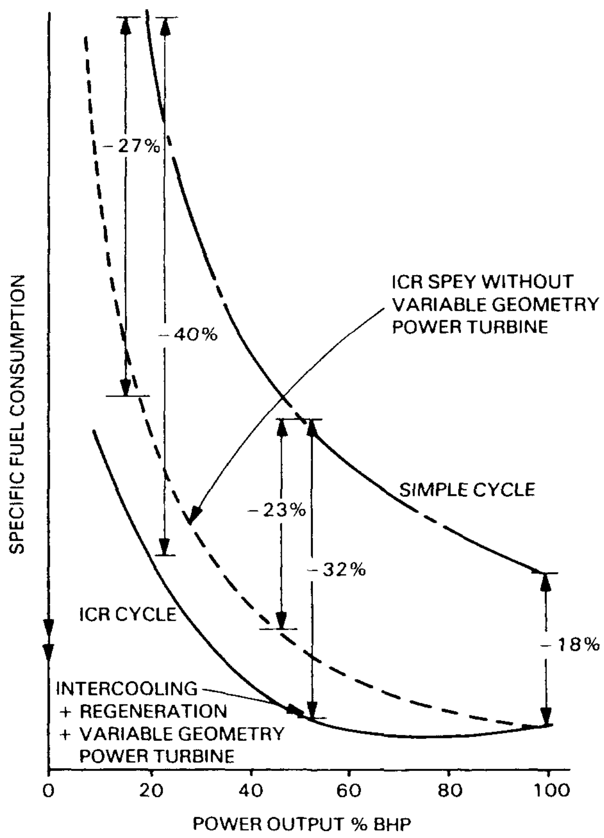

FIG. 3—VARIATION OF SPECIFIC FUEL CONSUMPTION WITH POWER

more efficient InterCooled and Regenerated engine (ICR). The ICR Spey is currently attracting considerable interest in the U.S.A. and is a strong candidate for the newly formed Advanced Gas Turbine programme. The U.S. Navy has a mandate from Congress to increase fuel efficiency by 30% and funds are allocated for a programme to introduce the new engine by 1995.

FIG. 3 shows a part load specific fuel consumption comparison between ICR and simple cycle gas turbines. Massive improvements in part load efficiency are predicted which make the ICR engine competitive with diesels and must make it a front runner in any future propulsion study.

Rolls-Royce would not normally expect to be able to compete in the U.S.A. market. However, in this case they are in partnership with Allison and Garrett who are both U.S. gas turbine giants. If Rolls-Royce do win the business, and heat exchanger dimensions can be contained within current design proposals, it is likely that the ICR Spey will be the engine of all our futures.

Reference

1. Harry, N. J. F. V.: Marine Spey—a short cut to longevity; *Journal of Naval Engineering*, vol. 29, no. 1, June 1985, pp. 53–59.