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[i]RTM322 – EXCEEDING EXPECTATIONS.

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ABSTRACT

The Anglo-French RTM322 engine has been developed to meet the military need for a common powerplant capable of satisfying the global operational requirements of land, sea and air forces. The provision of an engine which meets the rigorous demands of reliability, maintainability and testability (as well as being able to offer power growth options as capability demands increase during the operational lifetime of the aircraft) provides significant benefit opportunities to the front line operator and the equipment manufacturer. Such mutual benefits include enhanced logistic support afforded by the ease and interchangeability of engine modules/components between aircraft types and reduced acquisition and inventory costs. This paper summarises the design concepts and parallel development/aircraft integration programmes of the RTM322 engine in three platforms and reflects upon the achieved reliability of the product over the first two years of in-service operation.

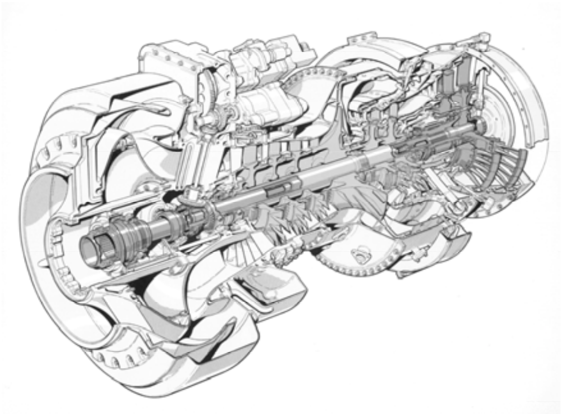
INTRODUCTION

In the late 1980's, all three UK Military Service sectors identified requirements for the acquisition of modern helicopters within their respective fleets. At the same time, the changing role of the UK forces was highlighting the need for world-wide deployable capability. The UK Ministry of Defence (MoD) recognised this situation as an opportunity to introduce some commonality into its operations and to reap benefits of synergy from a new force structure.

With three fundamentally different operational roles requiring different air vehicles the challenge was set to provide solutions to the propulsion requirements utilising a single engine type. The design solution had to be capable of operating in the broader, global environmental conditions imposed as a result of the post 'cold war' changing role of the armed forces. This situation was reflected in the UK MoD Strategic Defence Review of the late 1990's.

The single engine type was designed to rigorous standards that embraced not only North European operational requirements, but also the need to deploy helicopter units world-wide (with no degradation in operability).

Utilising a state-of-the-art, Full Authority Digital Engine Control (F.A.D.E.C.) system and an advanced Inlet Particle Separation (IPS) unit, the engine configuration includes the flexibility to be utilised, at optimum levels, in diverse roles including those of Anti-Submarine Warfare (ASW), Tactical Troop Transportation and Support (TSH) and battlefield Attack Helicopter (AH).



The existing RTM322 installations in UK MoD service comprise two variants of the European Helicopter Industry EH101 and the Westland WAH-64 Apache. In addition, an increased power version has been selected for the N.A.T.O. Helicopter Industry NH90 aircraft, ordered by the French, German and Dutch governments. Further installations into other existing (and new) airframes (for both civil and military applications) would benefit from the existing or power-growth versions (up to 3,000s.h.p.) already defined.

The resulting commonality, flexibility and designed-in reliability and maintainability features offer the prospect of significant logistic advantages to both the operator and industry. Furthermore, opportunities to develop innovative after-market support options become a reality, leading to benefits in vastly improved and sustainable operational readiness as part of an affordable package.

DESIGN CONCEPT

Market demands for new aircraft engines are no longer dominated by initial unit costs, but include, as equal importance, a 'through-life' affordable package which will deliver operational and cost effective solutions. As such the modern engine is required to meet the rigorous standards that such criteria demand, including the 'standard' Reliability, Maintainability & Testability (R, M & T) requirements born out of the RM&T2000 initiatives of the 1980's/90's. In addition, it is recognised that reductions in pilot workload (particularly important in the military rotorcraft field) should be afforded equal importance.

Such diverse requirements inevitably lead to design compromises and it is the optimisation of such that results in a product that best meets the original intent of all concerned, from inception.

THERMODYNAMIC CONSIDERATIONS.

The fundamental parameters influential in such designs include:

- Overall Pressure Ratio (OPR)
- Mass flow
- Turbine Entry Temperatures

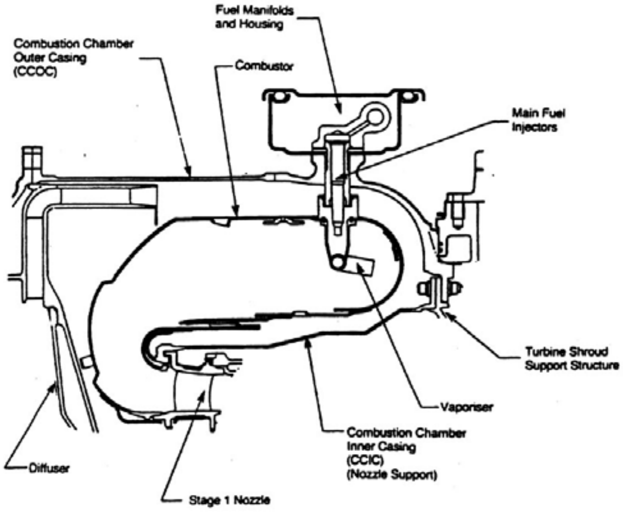
The typical values of these parameters (at SLS T/O) are illustrated below:

Application	Power (hp)	OPR	Core Mass Flow (lb/s)	TET (K)
EH101 (ASW)	~2100	~14	~12.5	1450 – 1500
Apache	~2100	~14	~12.5	1450-1500
EH101* (TSH)	+7%**	~14.5*	~13	1500-1575
NH90#	+14%**	~15.25	~13.75	1500-1550

*"Throttle Push" ** From EH101(ASW) levels
Uprated compressor

Low 'through life' costs are generated via robustness of component design and as such lead to a machine which will operate at moderate OPR's and TET's, thus reducing compressor load and resulting in turbine longevity and power growth margin. Such factors lead to the necessity to design a higher mass flow machine which tends to be detrimental in terms of specific fuel consumption (s.f.c). However, the incorporation of a F.A.D.E.C system, as a fundamental design requirement, affords the opportunity to optimise engine characteristics throughout the required operational envelope thereby minimising this apparent shortcoming.

In considering F.A.D.E.C, the thermodynamic stability of the engine needs to be considered if total advantage of the system is to be realised. In particular, the speed of response of the controller must be optimised to match the engine characteristics without the risk of compressor surge or combustor instability. Although the RTM322 F.A.D.E.C incorporates surge detection/protection and flame – out protection logic, it is fundamental to the design of the engine that its stability margins remain sufficiently robust to enabled any future 'throttle – push' power enhancement requirements to be accommodated.



One of the key contributors to the stability of the engine is the incorporation of the vaporiser combustor system. A major characteristic of the design is the high weak extinction boundary afforded through the relatively low primary zone inlet Air/Fuel Ratios (AFR's) within which the combustor operates. Full advantage is therefore taken in the optimisation of the fuelling/combustor system, fully integrating it with the F.A.D.E.C and hence providing a complete engine system having the required rapid response to control system demands.

F.A.D.E.C.

The F.A.D.E.C. system provides for complete control of the engine which, in addition to automatic start sequencing, fuel management, compressor variable geometry scheduling and power shaft output speed control, includes Gas Generator and Power Turbine overspeed protection, overtemperature protection, fault detection and failure management. In addition the F.A.D.E.C. provides multiple signals to the cockpit displays and engine speed and temperature signals to the Aircraft Management System (AMS) where they are processed via validated algorithms in order to monitor engine health and life usage.

The system has an independent dual channel arrangement in which the second channel provides the back-up (or redundant) system with independent power supply and no loss of functionality over the alternative channel. Selection of the second channel in the case of failure is automatic and ‘bump-free’. All flight critical electrical input and output signals are duplicated so that no single failure will result in a mission abort.

Engine operation throughout the flight envelope is optimised and pilot workload minimised by the provision of automatic control and operating functions. The system permits the use of a simple pilot interface in the helicopter for engine control; start-up, transition to/from rotor governing and shutdown operations are combined into a single condition switch for each engine.

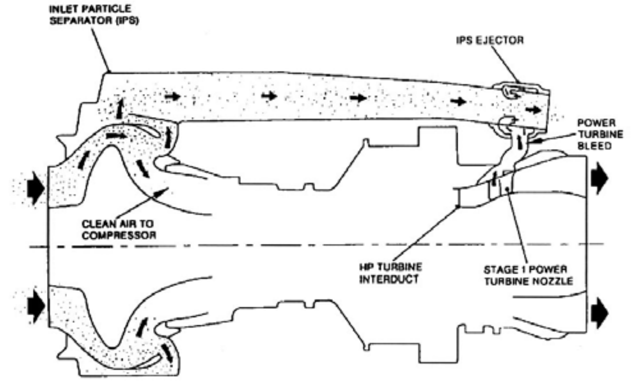
Incorporation of F.A.D.E.C as a basic design criterion affords the opportunity to optimise the total engine/control system with the dynamic characteristics of specific aircraft drivetrains. This ability was exploited fully during the WAH-64 (Apache) engine integration programme carried out at the Boeing, Mesa (Az.) plant.

It became evident that, due to the relatively low inertia of the aircraft rotor system, compared with that of the EH101 application, the acceleration response of the engine during rapid collective ‘pulls’ was such as to initiate drivetrain resonance following engine/drivetrain ‘coupling’. Finessing of the control laws within the last 10% of acceleration provided a solution in which no discernable detriment to the desirable engine response rate resulted.

The F.A.D.E.C. system, as well as contributing to outstanding operational advantages, also facilitates improved maintainability through the continuous monitoring of key engine parameters via its sensor network throughout the engine. The built-in test capability of its circuitry and its ability to perform continuous testing of the Line Replaceable Units (LRUs) adds to this advantage. Additionally, the system transmits engine health and usage data via the ARINC link to the AMS providing complete maintenance diagnostic facilities to the ground crew as well as (via appropriate algorithms) Power Performance Index and Exceedence Monitoring capabilities.

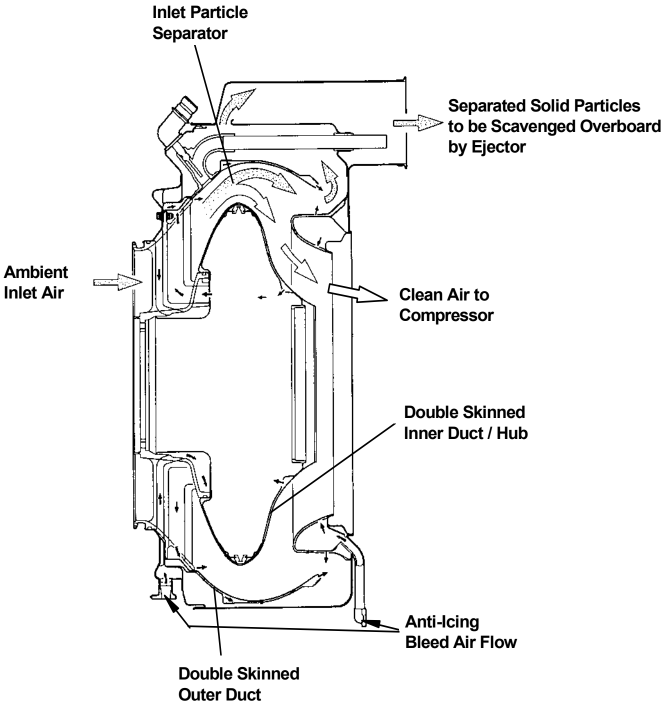
It is only through F.A.D.E.C. technology, and the use of these algorithms and real time data that more accurate monitoring of the Critical Part lives is achieved. This allows full life usage to be extracted from the engine components prior to replacement resulting in the obvious benefits of increased aircraft availability and reduced Life Cycle Costs for the operator.

INLET PARTICLE SEPARATION.



The RTM322 engine incorporates a unique Inlet Particle Separator (IPS) module. This unit, having no moving components, utilises an inter – stage turbine ejector bleed system in combination with vortex separation of airborne particles via the ballistic/aerodynamic design of the IPS scroll. Testing to MIL-E-50007 requirements has demonstrated particle separation efficiencies in the mid 90% range.

The separation of particulate contaminants from the inlet air is a function of particle size. The inertia of the particles is used to deviate their trajectories from the general flow direction in a region of flow curvature. For small particles, typically below 50 to 100 microns diameter, drag forces tend to dominate the momentum effect for which it is necessary to create a region of very high flow curvature to achieve separation. This region is located around the area of maximum diameter of the IPS.



The small particles are concentrated in the outer region of the flow for collection into the scavenge scroll. Larger particles have enough momentum to behave in a ballistic manner. In this case, control over trajectory is achieved by designing the separator so that collisions with the duct walls tend to focus the particle towards the scavenge section. A ballistic means of separation also applies in the case of foreign objects and bird strike debris. In both instances, the objects are directed into the scavenge section.

The lower pressure loss resulting from the absence of 'swirl/de-swirl' vanes enables the use of an ejector mechanism using turbine bleed with no moving parts to scavenge the duct rather than having to use an electric fan that would be susceptible to erosion and poor reliability. Thus the entire IPS mechanism on the RTM322 has no moving parts offering unparalleled levels of separation reliability, efficiency and reduced maintenance burden.

Extensive testing of the IPS has been performed and results have illustrated excellent separation of airborne debris and foreign objects. This was further substantiated throughout the engine qualification programme with the engine achieving the requirements laid down in Def-Stan 00-971 and Mil Spec AS/AV-E-8593E for the ingestion of sands, salt, hail, ice, water and birds.

MAINTAINABILITY/TESTABILITY

Simplicity was fundamental to the engine's design concept with the selected engine configuration offering benefits of robustness and low acquisition and life cycle costs. A low part count and the latest in manufacturing techniques further enhance the ownership cost savings inherent in this design.

An additional fundamental was the principle of designing for ease of maintenance. The principle aim was to maximise operational availability through the minimisation of downtime for scheduled and, should the need arise, unscheduled engine maintenance. This meant minimising the scheduled maintenance requirements and ensuring the engine design facilitates rapid engine recovery from unscheduled events. To this end maintenance teams from the UK Royal Navy and Royal Air Force as well as a specialist US evaluation team were used in the engine design phase to validate the "no compromise" approach to ease of maintenance.

ENGINE DEVELOPMENT/QUALIFICATION

The RTM322 engine has been qualified for service use in all three UK MoD new aircraft which will form the nucleus of the joint operations covering battlefield, maritime and Tactical Troop Transportation roles. These aircraft are the Westland WAH 64 variant of the model 'D' Apache attack helicopter and the two Mks (one being equipped with a ramp) of the European Helicopter Industry EH101 Merlin.

Of the three, the Merlin Mk1 (ASW) aircraft was the first to enter service (with the Royal Navy at the end of 1998). Included in the initial operational phase has been an intensive period of engine reliability demonstration. This comprised a dedicated group of 5 aircraft from 2 squadrons exposed to an intensive period of operations and deployments from ship and shore bases.

UK Army Air Corps (AAC) WAH64 Apache and Royal Air Force Merlin Mk3 aircraft are currently involved in Service Evaluation and pilot training programmes.

RELIABILITY

During the initial In – Service Reliability Demonstration phase all flights were closely monitored for engine operation defects. This ISRD phase of the RN Merlin Mk 1 A/C, was completed earlier this year with a total of nearly 3500 engine flying hours having been accumulated.

Total flying hours with the Mk 1 aircraft exceed 16500, whilst those for the RAF Mk3 variant and AAC WAH 64 Apache installations amount to approximately 2000 & 3500, respectively to date. During this time only two LRU's were recorded as failures, with no engine removals, for any cause, having been experienced.

The ISRD data indicates that the contracted Mean Time Between Failure (MTBF) requirement for the engine is greatly exceeded, verifying the in-built reliability that was a fundamental design criterion of the engine from the outset.

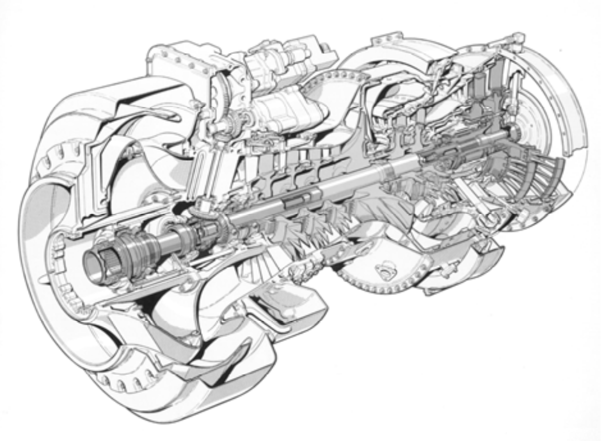
OPERATIONAL/OEM MUTUAL BENEFITS.

In addition to the clear operational benefits that such reliability levels produce, through – life cost advantages are also evident. Such advantages, amplified by the high degree of commonality between the applications, can result in added benefits to both the acquisition customer and the Original Equipment Manufacturer (OEM).

A change of OEM emphasis from equipment supplier to 'tailored' service provider allows the customer the opportunity to concentrate upon its prime role of providing a coherent, flexible and effective defence force. In so doing, the equipment provision challenge is vested in the OEM, that 'equipment' including the entire suite of essential services (documentation, repair & overhaul, spare engines & LRU's etc.) that is required to sustain the requirements of the modern, integrated defence force. Thus, the availability of all engine related services can be provided at levels appropriate to the operational readiness requirements of the end - user

This change in service support is, I believe, inevitable. The current major debating point probably focusing upon the **degree** of support offered; that is, whether industry could (or should) be included in 1st &/or 2nd line activities in additional to the 'traditional' engine supply/spares support concept.

CONCLUSION.



The RTM322 engine was designed to the exacting standards demanded by the customer for joint service operations in the twenty first century. The focus upon all aspects of the quoted requirements of the platform (rather than mere attention to the contracted engine specification) has resulted in the provision to the operator of a power system that best meets these needs.

Meticulous attention to the number of, and, access to Line Replaceable Units (LRU's) ensures the highest level of operational readiness. The inherent robustness of the turbomachinery has already surpassed expectations in demonstrating the potential longevity of the engine which will reap benefits of low through life support costs, whilst affording industry the opportunity to offer innovative support concepts, enabling the end-user to concentrate upon the vital front line defence role.

The optimisation of the F.A.D.E.C. system into total aircraft drivetrain management has been proven to vastly reduce pilot workload and thereby improve the operational effectiveness of the weapon system.

> ***"The best thing about Flying a Helicopter powered by RTM322 engines is the ability to forget about them"***
>
> ***(Rotor and Wing International)***

All these factors were initiated by an understanding of end-user requirements, which were given equal and definitive importance from the inception of design. It is the result of such understanding that the engine, during its first two years of service operation/evaluation has exceeded the expectations of the contracted customer and equally (if not more) importantly the end-user/operator.

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