THE SEA KING CENTRISEP ENGINE AIR PARTICLE SEPARATOR

by

COMMANDER J.G. APPS BSC R.N
(formerly Defence Helicopter Support Authority —HS11b)

ABSTRACT

Advanced, all-weather, engine intake environmental protection is now available for the SEA KING. The Centrisep Engine Air Particle Separator (Sandfilter), which was deployed successfully on RN aircraft in the Gulf war, has now been modified to incorporate a Snow and Ice Protection System (EAPS/SNIPS) and is suitable for fitment as standard equipment to the RN and RAF SEA KING fleets.

Fleet wide fit of Centrisep EAPS/SNIPS will confer clear operational and flight safety benefits in addition to a significant reduction in overall aircraft cost of ownership. The Defence Helicopter Support Authority is now leading a multi-million pound procurement programme to equip all RN and RAF SEA KINGS with EAPS/SNIPS by 1997.

This article will cover :

- Design and development of the EAPS/SNIPS.
- Operational and cost benefits.
- Procurement and embodiment programme.

J.Nav.Eng., **35**(3), 1995

FIG. 1—SEA KING MK 4 FITTED WITH CENTRISEP FILTER

Introduction

It is well known that small gas turbines are susceptible to performance degradation or catastrophic failure due to:

- Foreign Object Damage (FOD).
- Compressor blade fouling or erosion.
- Hot-end corrosion.

This is particularly the case with helicopter engines. Operations from unprepared sites, hovering at low height over the sea, or flight in icing conditions, presents the engines with a debilitating cocktail of salt spray or particles of varying size along with large volumes of intake air. Crude intake protection is currently provided on the SEA KING by a mechanical Foreign Object Deflector (commonly known as the 'Barn Door'). But, in the combined RN and RAF SEA KING fleet of 140 aircraft, the annual cost of GNOME engine rejections for FOD alone continues to be in excess of £1.3M.

Highly efficient environmental protection for helicopter engines can be provided by intake systems incorporating multi-tube vortex separators, often referred to as Engine Air Particle Separators (EAPS). These can be easily retro-fitted to most existing helicopter designs and provide significant operational and flight safety benefits in addition to potentially large savings in engine through-life costs. Successful helicopter EAPS installations have been in military and civilian service since the late 1960's and installed in such varied types as the Boeing CHINOOK CH-47 and Russian Mil Mi-8.

An EAPS based design, the Centrisep Sandfilter, was procured in 1979, with the initial RN purchase of SEA KING support helicopters (Mk4). This was to replace the Barn Door, as role equipment, for desert operations. These provided very high sand filtration efficiency and almost complete protection against FOD, but the absence of an acceptable icing clearance virtually prohibited their use in

temperate climates. Following successful deployment of the RN stock of 32 Sandfilters, to provide essential protection against compressor erosion for RN SEA KINGS operating ashore during the Gulf war, the Sandfilter design has been modified to provide all weather environmental protection. Upgraded filters have now been deployed successfully on SEA KING Mk4 aircraft (FIG. 1), in support of operation GRAPPLE in the Former Yugoslavia since mid 1994.

Investment appraisals to support the procurement of a full SEA KING fleet fit of this new Centrisep EAPS/SNIPS (Snow and Ice Protection System) equipment has shown cost amortization within 2 years.[1,2] A multi-million pound, 'spend to save' procurement programme, to equip the whole RN and RAF fleets as standard fit by 1997, is now being led by the Defence Helicopter Support Authority (DHSA). This article will cover:

(*a*) Design and development of the filter and the associated integration with the airframe.

(*b*) Operational and cost benefits of the filter.

(*c*) Procurement programme.

Design and development of the SEA KING Centrisep

Common design features of the Sandfilter and EAPS/SNIPS unit

The Centrisep EAPS assembly consists of an aluminium alloy housing which is mounted forward of the engine intakes (FIG. 2). Separator panels situated at the top, front and sides of the housing contain numerous vortex generator tubes, and the aerodynamic characteristics of these tubes enables engine protection to be achieved.

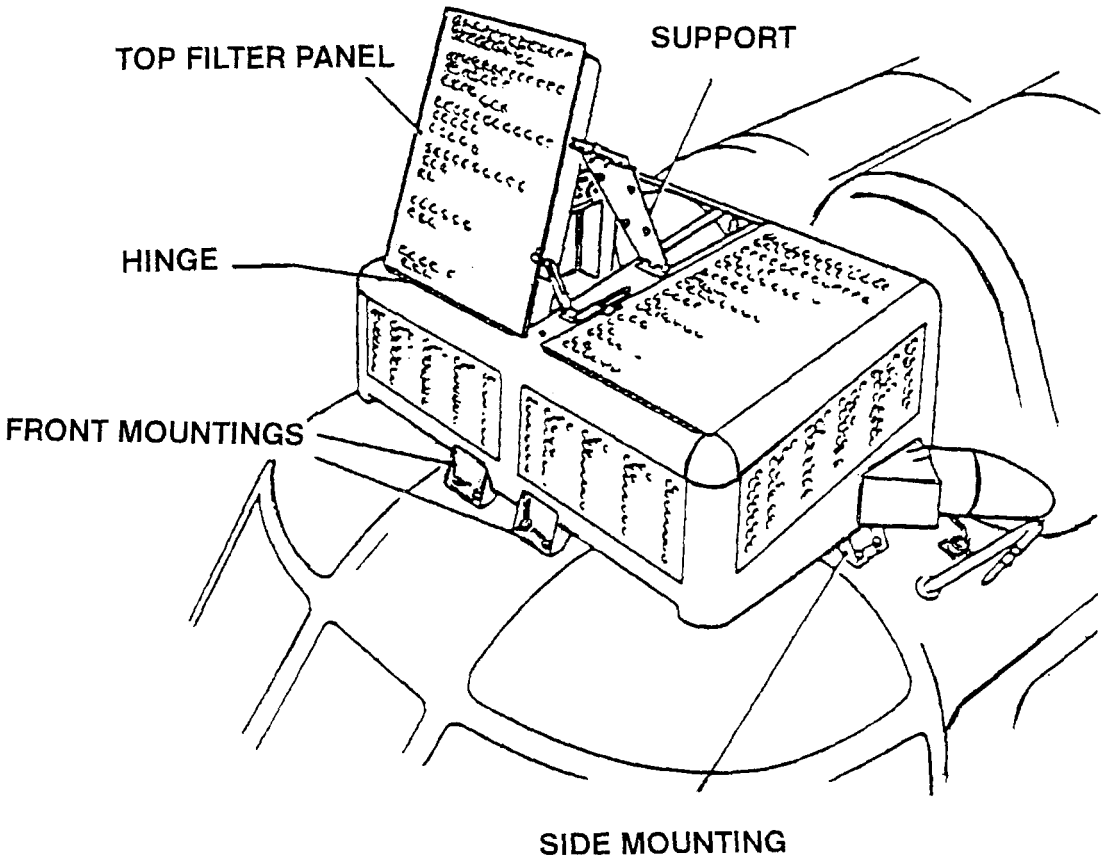

FIG. 2—THE SEA KING CENTRISEP FILTER SHOWING THE VORTEX TUBE PANELS. THE TOP PANELS ARE HINGED TO ALLOW SERVICING

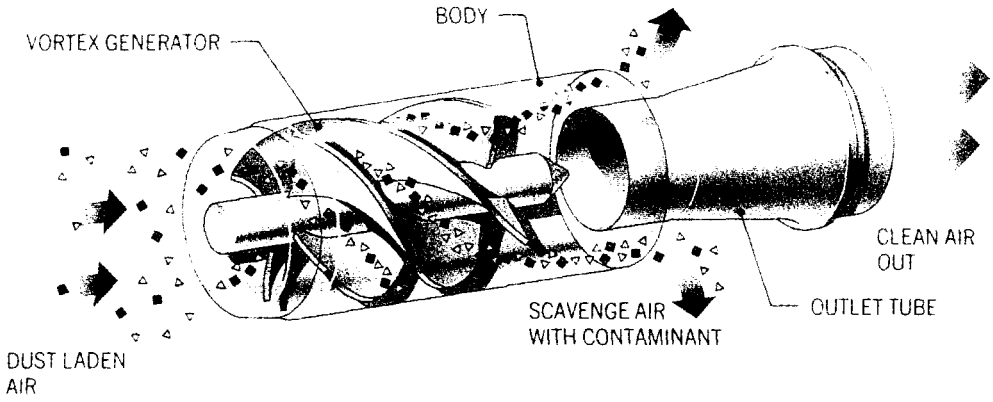

FIG. 3—OPERATING PRINCIPLE OF VORTEX GENERATOR TUBE

The operating principle of the vortex generator tubes is shown in (FIG 3). Contaminated air is drawn through the tube by engine suction and is caused to swirl by the fixed vortex generator. The swirling flow causes the heavier dirt particles and water droplets to be thrown radially outwards, by centrifugal force, toward the wall of the body. Electrically driven scavenge fans, located in the frame of the EAPS, draw the contaminated air through the annular gap between the vortex tube body and the outlet tube and eject it overboard. Clean air is delivered to the engines through the outlet tube. The scavenge paths in the SEA KING EAPS are shown in (FIG 4).

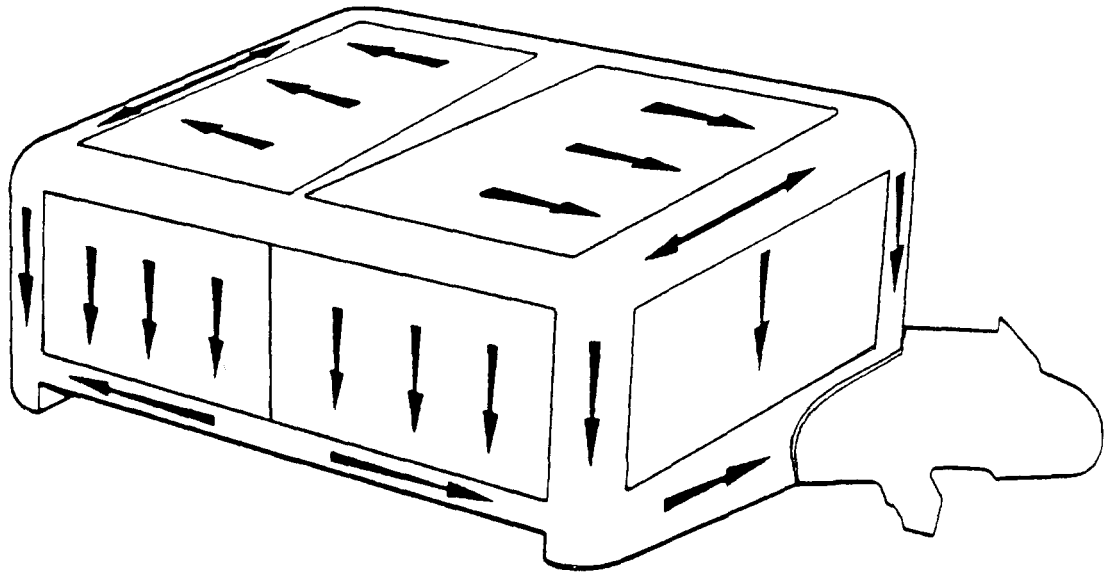

FIG. 4—SCAVENGE PATHS ON SEA KING CENTRISEP FILTER

Separation efficiency varies with:

- Type of contaminant.
- Aircraft speed.
- Engine power.

For sand it is about 90% and salt spray between 70% and 80%.[3] Separation can be related to compressor blade erosion levels and hence to engine life. (FIG. 5) shows a comparison of dust separation efficiency against engine life improvement.[4]

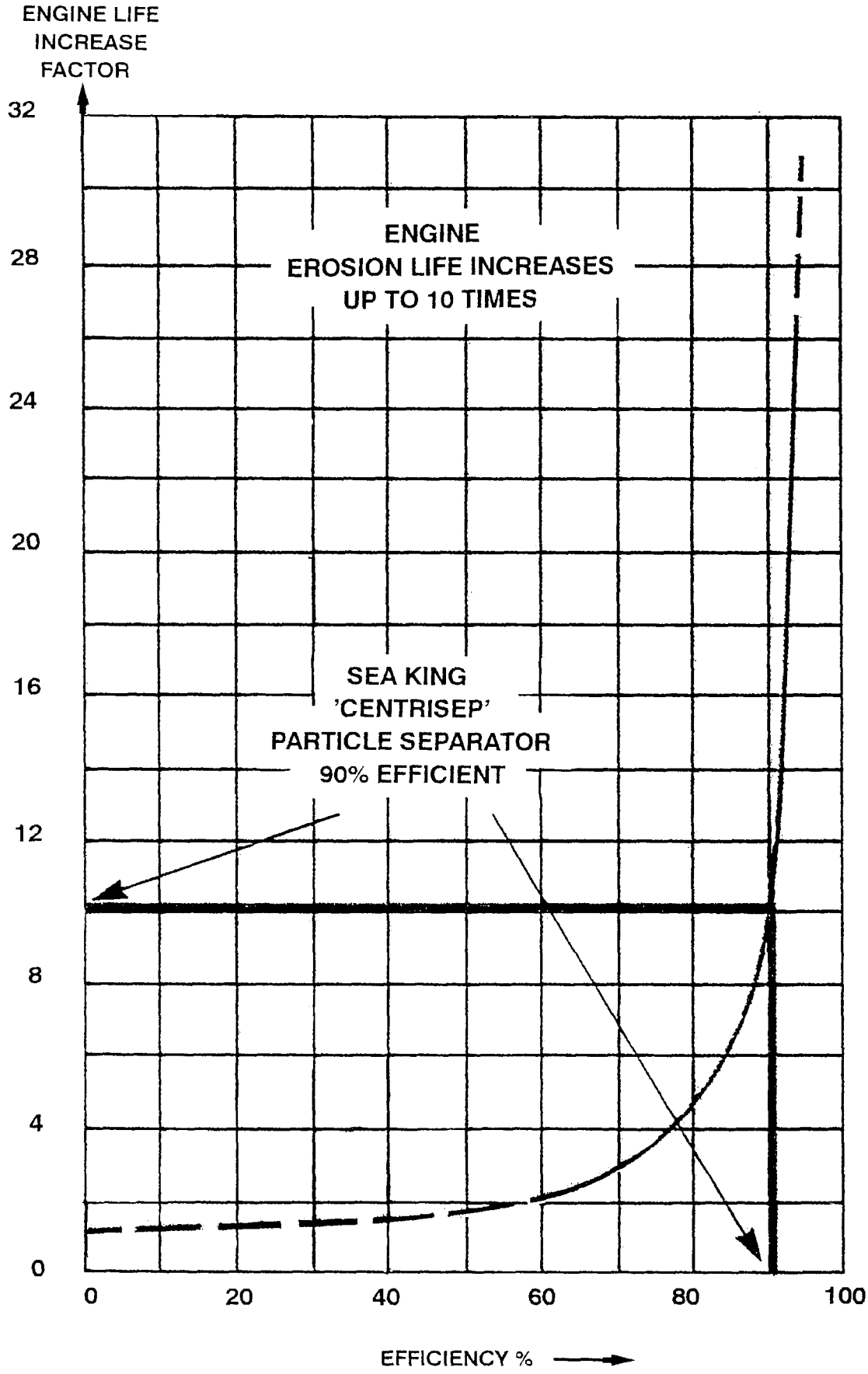

FIG. 5—EFFECT OF SANDFILTER ON ENGINE LIFE

Modification of the Sandfilter design to incorporate SNIPS

The SNIPS modification package was developed between 1991 and 1994 by the Sandfilter manufacturers, Aircraft Porous Media Europe (APME) in response to the MoD requirement for an acceptable icing clearance. The development process included MoD sponsored cold weather trials of a prototype modified filter on a Royal Navy SEA KING Mk4 in Canada, during the winter of 1991/2. The trial was undertaken by the Aircraft and Armament Evaluation Establishment (now DRA) Boscombe Down.

These trials resulted in recommendations for a Controller Aircraft Release flight clearance, but identified the requirement for thermal overload protection of the scavenge fan motors. This additional modification, and the necessary associated changes to the airframe fixed fittings, has delayed the introduction to service of the fully modified EAPS/SNIPS units until early 1995. To satisfy an Urgent Operational Requirement (UOR) to deploy intake protection to SEA KING Mk4 aircraft in Operation GRAPPLE, an interim flight clearance was given for the EAPS/SNIPS units equipped with normal scavenge fans.

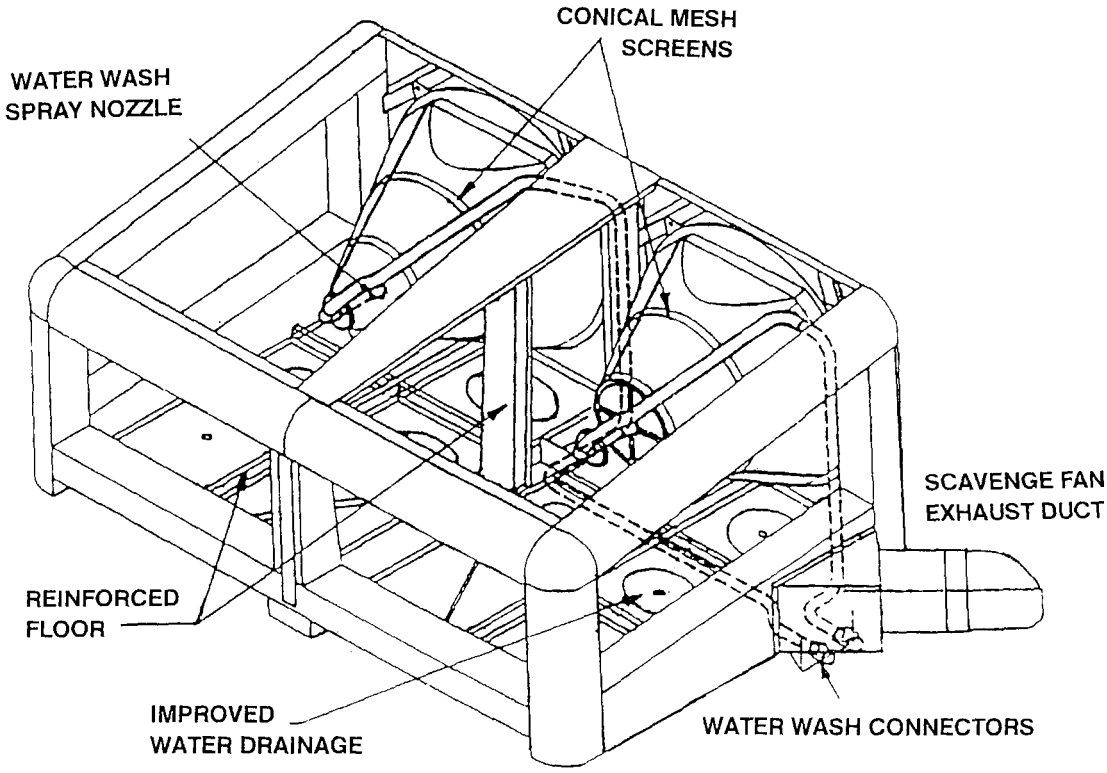

FIG. 6—MODIFICATIONS INCORPORATED IN SEA KING CENTRISEP EAPS/SNIPS FILTER

The Sandfilter is upgraded to full EAPS/SNIPS standard (FIG. 6), by inclusion of the following:

(*a*) *Conical stainless steel mesh screens.*

These provide secondary filtration against any FOD or ice over 2mm and also protect against cross-ingestion after a single engine failure. Flexible circular lip-seals provide the interface with the engine bellmouths.

(*b*) *Integral compressor wash kit comprising water spray nozzles, piping and connectors.*

Quick and efficient engine washing/inhibiting is now possible without opening the separator panels.

(*c*) *Structural strengthening to EAPS duct/frame assembly filter box.*
This improves the EAPS structure enabling it to withstand higher differential pressures during icing.

(*d*) *Improved water drainage.*
This minimizes water/slush accumulation on plenum floor panels. This enables the aircraft to operate in heavy rain/sleet conditions, while also reducing the risk of engine flameout.

(*e*) *Scavenge fan thermal overload protection.*
This prevents overheating or fan failure in the event of locked fan rotors due to ice formation.

Integration with the airframe

The airframe fixed provisions necessary for fitment of Centrisep EAPS consist of:

(*a*) Bolt holes and captive nuts for the filter feet and centreline attachments.

(*b*) Electrical supply to the scavenge fans.

(*c*) Pilot's control panel giving fan on/off selection and doll's eye indication.

SEA KING Mk4

As the Sandfilter was supplied as standard role equipment for the SEA KING Mk4, only minor aircraft electrical modifications are required to accommodate the EAPS/SNIPS unit. These comprise revised cabling and connectors for the new scavenge fans.

Centrisep EAPS units are supplied with only the 7 centreline attachment holes jig-drilled to match the airframe. The mounting holes in the 4 feet are back drilled from the airframe holes. Minor dimensional differences between individual airframes, means that each unit effectively becomes unique to one aircraft. With the current requirement to move the limited stock of EAPS between aircraft, this has caused some problems. However, this is being overcome in the short term by procuring additional new feet, making sets of feet aircraft specific, and changing feet when a filter is moved between aircraft. In the long term, movement between aircraft should be unnecessary as all aircraft will be fitted.

SEA KING AEW Mk2, Mk3/3A, Mk5/6

Apart from a few Mk5 aircraft which were equipped prior to the Gulf war to accept the Sandfilter, the airframe fixed provisions for EAPS/SNIPS unit all require full design and development by the aircraft Design Authority (DA), Westland Helicopters Ltd (WHL). This programme will commence in early 1995, with an accelerated programme of combined development and kit manufacture for the simpler SEA KING Mk5/6 installation.

Interchangeability between aircraft will only be a potentially significant problem in the Mk5/6 fleet as only enough EAPS/SNIPS units have been procured to equip aircraft allocated to squadrons. Units will be moved from aircraft entering deep maintenance to those returning to the active fleet. A DA study is underway to address this problem in the long term, but it is likely that the Mk4 solution of changing feet will be adopted.

Operational benefits

The immediate operational benefits are most apparent in the Support Helicopter fleet, where the operating regime from often unprepared sites results in a high risk of FOD and consequent risk to aircrew and aircraft in hostile theatres. The

operational case is less strong for the other marks, but the flight safety case and performance/endurance benefits are still significant. These benefits are:

(*a*) Full protection against FOD, ice, snow and sand ingestion.

(*b*) Fewer engine removals resulting in increased operational availability.

(*c*) Prevention of cross-ingestion of FOD from an engine failure.

(*d*) Reduction in intake losses to less than half those for the Barn Door [3,5] giving improved:

- Specific fuel consumption.
- Aircraft endurance.
- Hot and high performance.

(*e*) Improved airflow into engine intakes, compared to the FOD shield, which will reduce torque mismatch in certain cross wind conditions.

(*f*) Reduction in potentially severe power loss associated with fouling of compressor blades with salt, during prolonged hovering over the sea.

(*g*) Simplified compressor washing/inhibiting operations resulting in increased operational availability.

(*h*) Improved upward field of vision from the cockpit.

Cost benefit

The fleet fit of Centrisep EAPS/SNIPS will result in a significant reduction in the cost of ownership of the SEA KING fleet. Major savings will be achieved by:

(*a*) *Reduction in ECU through life costs.*

This will be through:

1. Elimination of rejections for FOD and subsequent repair costs.
2. Reduction in performance related rejections and subsequent repair costs.

Reduction in Part Life rework and overhaul costs because of reduced spares usage, particularly compressors.

(*b*) *Redundancy of intake flare heater mat.*

The Centrisep design obviates the need for a serviceable heater element in the intake flare, thus enabling non-functional intakes to be retained in service. This will remove the need to procure additional new flares with an associated annual saving in excess of £1M.

(*c*) Reduction in fleet fuel consumption.

The expected reduction of 4% in specific fuel consumption,[6] will give a commensurate saving in fleet fuel usage.

(*d*) *Redundancy of FOD shield fluid anti-icing system (TKS)*

Giving reduced cost of ownership through reduced maintenance.

Procurement and embodiment programme

Equipment and timescales

The key points of the procurement and embodiment programme required to achieve an RN and RAF SEA KING full fleet fit of Centrisep EAPS/SNIPS are as follows:

(*a*) Modification of existing 32 Sandfilters to EAPS/SNIPS standard by APME. (Complete by March 1995).

(*b*) Purchase of 94 new EAPS/SNIPS units from APME. (Complete by May 1995).

(*c*) In-service modification of existing SEA KINGMk4 airframe fixed fittings, with WHL modification kits, to accommodate new scavenge fans. (Complete by mid-1995).

(*d*) Development by, and subsequent purchase from WHL of new airframe fixed fittings for SEA KING AEW Mk2, Mk3, Mk3A, Mk5 and Mk6 aircraft. (Complete by late 1996 for Mk5/6 and late 1997 for other Mks).

(*e*) Installation of all filters and fixed fittings into airframes. (To be complete as soon as possible after delivery of airframe fixed fittings).

Funding

Funding of this multi-million pound procurement programme has been by a combination of:

(*a*) Directorate of Helicopter Projects for development costs.

(*b*) Operation GRAPPLE UOR funding for 17 upgrades of Sandfilters to EAPS/SNIPS standard.

(*c*) Chief of Fleet Support (CFS) Top Level Budget FY 94/95 underspend allocation for 15 upgrades and 77 new EAPS/SNIPS filters.

(*d*) DHSA LTC provision for 17 EAPS/SNIPS filters and all airframe fixed provisions.

Contracts

The major contracting action was for the new build filters for delivery in early 1995. As this was largely funded from the CFS 94/95 underspend, it was imperative that an in-year spend was achieved. Confirmation of availability of funding was only received in July 1994 and this required a contract for some £5M to be let within one month. The collocation of engineering, supply, finance and contracts staff within the Multi Disciplinary Group (MDG) based DHSA, enabled this to be achieved by:

(*a*) Rapid, direct communication between involved disciplines.

(*b*) Dovetailing RN and RAF requirements to maximize purchase quantity and reduce unit price cost.

(*c*) Single point of contact with manufacturer.

Conclusion

The Centrisep EAPS incorporating the SNIPS, provides highly efficient intake environmental protection for the SEA KING helicopter. The design has now matured fully and is suitable for fitment, as standard equipment, to all RN and RAF aircraft.

Fleet wide fit of Centrisep EAPS/SNIPS will confer clear operational and flight safety benefits, in addition to a significant reduction in overall aircraft cost of ownership. Investment cost amortization within 2 years is predicted, with savings arising primarily from engine reliability improvement and equipment redundancy.

The DHSA is now leading a multi-million pound procurement programme to equip the RN and RAF SEA KING fleets with Centrisep EAPS/SNIPS. The programme will largely be complete by 1996. The tri-service MDG concept of the DHSA has facilitated:

- Rapid identification and amalgamation of available funding.
- Maximum value for money through the combining of individual services requirements.
- Minimal delay in contracting action.

References

1. Defence Helicopter Support Authority *D/DHSA/16/8/1/46 dated 5 May 94*: Modified Centrisep Filter -SEA KING full fleet fit.
2. SM(Hels)29a(RAF) *STC/5347/5/6 dated 24 Jun 91*: SEA KING HAR Mk3-Centrisep intake filters.
3. Rolls-Royce *ENG/MPN/297/8/AMB dated 20 Sep 90*: Use of Centrisep Sandfilter intake on SEA KING.
4. Curve based on Detroit Diesel Allison 570-k Gas Turbine Installation Manual and Applied Technology Laboratory, Ft. Eustis VA, Data.
5. Westland Helicopters Limited *Brochure B3341 dated Nov 93*: Westland SEA KING/Commando Engine Air Particle Separator (EAPS).
6. Rolls-Royce *PSG/GNO/5743/RT/T070 dated 12 Oct 90.*