Leaflet 70-80 Guidance Material for Ageing Engine Continuing Airworthiness

1 Introduction

1.1 This guidance material has been produced following a number of accidents and incidents involving the serious failure of high calendar time engines or their accessories.

1.2 The intention of this guidance is to aid Approved Organisations and provide continuing airworthiness recommendations for the management of engines against potential calendar time related deterioration. This is particularly relevant to certain categories of non-Part-21 aircraft types where the product is no longer actively supported by a type design holder or engine manufacturer.

1.3 If the Original Equipment Manufacturer (OEM), does not provide any recommended calendar time between overhauls, under a low utilisation operation regime, this can result in an engine remaining on wing for a protracted period before removal for workshop strip/overhaul or repair under the TBO limit (in hours or cycles run). Additionally, it is unlikely that the OEM considered continued operation of the engine many years after it was withdrawn from military service.

1.4 This guidance provides a framework of generic best practices as examples of how to allow ageing engines to continue to operate with acceptable standards of continuing airworthiness.

1.5 Where an Alternative Means of Compliance (AMOC) is used as an alternative to engine overhaul, generic maintenance programmes (e.g. LAMS) are not appropriate without customisation and subsequent individual CAA approval.

2 Applicability

2.1 This guidance is intended specifically for the following categories of fixed and rotary wing aircraft and engines:

a) Non-Part-21 aircraft types with Certificates of Airworthiness powered by gas turbine engine(s) or by radial piston engine(s) of ≥ 450 hp;

b) Ex-military aircraft with National Permits to Fly powered by gas turbine engine(s) or radial piston engine(s) of ≥ 450hp.

2.2 This guidance is not applicable to engines installed on aircraft types classified as ‘Complex’ in accordance with CAP553, BCAR Section A, Chapter A8-25 Supplement 2

2.3 While aimed at a specific group of high calendar time engines, owners and operators of other high time engines can consider the practices and the need for additional maintenance actions to ensure appropriate standards of continuing airworthiness are upheld. The principles laid out in this document may be useful for this purpose.

2.4 AMOC’s as an alternative to engine overhaul should only be considered if the service history of the engine since new or the last overhaul (TSN/TSO) is known. Engines that have reached 15-years since new or last overhaul where the service history is not known should be overhauled in accordance with OEM requirements.

3 Engine Manufacturer's Recommendations

3.1 Typically, ageing and ex-military engines do not have calendar time recommendations between overhaul quoted in the manufacturer's instructions for continuing airworthiness. Any limitations that have been imposed by the OEM, however, must be respected, such as whole engine and critical part hard lives, and cycle/hour times between overhaul, whichever comes first. Furthermore, ancillaries must be controlled within their OEM recommended lives.

3.2 Critical parts are typically those parts defined by the OEM (usually during the certification process) the failure of which are considered to be catastrophic at the engine level. For gas turbine engines, examples of critical parts usually include compressor and turbine discs, impellers, shafts and rotating seals, but varies between individual types, and are controlled by declared hard lives issued by the OEM.

3.3 Other instructions such as maintenance tasks, frequencies and inspections, as well as those for ancillary equipment should be respected.

4 Responsibilities of the Approved Organisations

4.1 In the context of ex-military Permit to Fly aircraft and non-Part-21 Certificate of Airworthiness aircraft with large radial piston or gas turbine engines (as defined in paragraph 2, above) it is expected or required that the aircraft will be maintained and managed by suitably approved organisations (e.g. BCAR A8-23/24/25).

4.2 The Continuing Airworthiness Management Organisation (CAMO-A8-25) will accordingly have responsibility for the control of engine records (including storage), hazard analysis and management of scheduled tasks within the Maintenance Programme including a regular review of the effectiveness of the programme.

5 Hazard Risk Assessment

5.1 The organisations maintaining and managing the aircraft should, where applicable, conduct a Hazard and Risk Analysis (HRA) on the continuing airworthiness aspects of the operation of engines with prolonged calendar lives since new or last overhaul to establish the levels of maintenance required. The HRA should include (as a minimum):

a) Safety critical failure modes such as in-flight fire, uncontained failure or propeller release (including a review of the type safety record considering UK and worldwide events)

b) An itemised listing of engine assemblies, critical parts, components, accessories and their associated overhaul tasks.

c) Identified risks (focussing on the effect of age-related deterioration e.g. corrosion, corrosion fatigue, stress corrosion cracking, hardening of elastomers, depletion of coatings etc.) that are present as a result of engine overhaul not being performed.

d) Proposed mitigating actions (additional inspections, monitoring and maintenance tasks to be included in the maintenance programme/Flight Manual/Flight Crew Reference Cards)

e) Other mitigations (e.g. multiple engine and system applications with

adequate redundancy and safety margins)

f) Residual risks.

5.2 Risks should be categorised as High, Medium and Low where:

High: Immediate risk of loss or substantial damage to engine including loss of thrust or power (in-flight fire, uncontained failure or propeller release)

Medium: Increased risk of engine failure which could result in a reduction of operational safety margins

Low: Minimal risk that can be managed within standard operating procedures engine of operation

5.3 If a Hazard Risk Assessment (HRA) is carried out as a means of compliance against this guidance material a formal review process should be carried out and a documented report compiled.

6 Alternative Means of Compliance

6.1 In the absence of OEM calendar time limitations on engine overhaul periods, Appendix I illustrates the option either to remove from service engines which have reached or exceeded 15 years of service since last recondition, overhaul or termination of last accepted storage period, or through an appropriately approved organisation (e.g. BCAR A8-25), construct a customised Alternative Means of Compliance (AMOC) programme. Such a programme, once established, should be considered for regular review at 3 yearly intervals.

6.2 It is possible that AMOCs could include a broad spectrum of in-service monitoring, inspection and partial disassembly actions (which could vary across different engine types) to verify that acceptable standards are being maintained, and to ensure that age-related deterioration is addressed. The basic elements and considerations of an AMOC are covered in the sections below.

6.3 AMOCs should reference specific engine serial numbers and the complete engine history including (but not limited to); date of last overhaul, TSN/TSO, storage history, Group A component lives (compressor discs etc.).

6.4 Where an AMOC is approved by the CAA, initial approval will be granted for three years to ensure a complete review of the AMOC and associated data is carried out.

7 Maintenance Programmes

7.1 It is considered important that the CAMO compiles a customised Maintenance/Management document for the engine that reflects all on-wing and off-wing scheduled AMOC maintenance such as inspections, trend monitoring, workshop visits, and partial disassembly where necessary. This should include references to the OEM's data such as manuals, instructions, bulletins and service letters where applicable. Similarly, any modification or de-modification status should be reflected, where applicable and relevant.

7.2 The elements of the Maintenance/Management document (including those required to be carried out off-wing, in a workshop) should be integrated in the aircraft maintenance programme.

7.3 The elements needed for a particular programme aimed at developing an

AMOC will depend upon the outcomes of the hazard assessments, data collection, analysis and review functions as outlined in Paragraph 5 and Appendix I. Paragraphs 8 and 9 detail some generic items which might be considered for inclusion in any possible programme, but it is accepted that the details of each individual programme will vary depending on the results of the preparatory work and the specific issues pertinent to the type being reviewed.

8 Gas Turbine Engines – Generic or Possible AMOC Elements

8.1 Particularly relevant for gas turbine engines, where possible the following data could be considered for collection at each engine run, as permitted by the type:

a) Pilot reports

b) Oil consumption rates/trend monitoring

c) Gas path performance trend monitoring (e.g. TGT, spool speed, etc.)

d) Engine run down times

e) Vibration monitoring (if system equipment is fitted)

f) Engine running times (including ground runs).

8.2 The above information should be formally recorded as relevant for each flight, and issues such as gas path parameters, vibration, and oil consumption trending plotted for evidence of datum shifts. It is quite likely that the optimum health monitoring could be carried out by flight crew at a steady state phase of engine operation.

8.3 Further maintenance tasks relevant to the AMOC may not be limited to those listed below as follows:

a) Borescope inspections of gas path components, either in-situ or with engine removed

b) Hot section inspections (with or without combustor removal)

c) Compressor inspections with compressor half case removal

d) Oil filter element sectioning and analysis

e) Oil analysis (i.e. SOAP)

f) Fuel contamination checks

g) Magnetic Chip Detector (where fitted) findings and recorded history

h) Jet pipe inspections for corrosion, cracking (particularly of circumferential welds) and evidence of damage, with heat shield or thermal blanket removal as required, to gain access

i) Bleed valve check/inspection

j) Module changes

k) Compressor water washes under OEM's instructions.

8.4 Inspections should clarify which areas and how the inspection is to be carried out. For example, compressor inspections should clarify whether rotating blades, static vanes and rotor path linings are inspected, and at which stages. If engine design and the manufacturer's instructions permit, then periodic compressor inspections, with the top casing removed, allow for a more thorough inspection to be carried out. Similarly, combustor-can removal could provide a useful insight into the status of combustor and initial turbine stage conditions. Inevitably, some inspections may require the removal of the engine from the airframe. Examples of additional generic AMOC inspections for consideration on gas turbine engines are detailed in Appendix II.

9 Large Radial Piston Engine – Generic or Possible AMOC Elements

9.1 Along similar lines to the operation of gas turbine engines, the following data should be collected following the operation of large radial engines, such as:

a) Pilot reports

b) Oil consumption rates/trend monitoring

c) Engine running times (including ground runs)

9.2 Additional piston engine checks and inspections could include but may not be limited to the following:

a) External engine inspection including crankcase and cylinder inspections

b) Cylinder compression including differential pressure checks

c) Borescope Inspection

d) Oil and fuel analysis

e) Engine power checks

f) Checks for evidence of hydraulic lock.

9.3 Tasks involving partial engine disassembly to ensure against the onset of the effects of age deterioration could include the following:

a) Removal and inspection of cylinder heads

b) Removal and inspection of cylinders

c) Disassembly of pistons, gudgeon pins and connecting rods for condition inspection

d) Crankshaft inspection in-situ

Examples of additional generic AMOC inspections for consideration on large radial piston engines is given in Appendix III.

10 Utilisation of Approved Maintenance Organisations

10.1 Appropriately approved maintenance organisations (e.g. BCAR A8-23) are required to carry out all maintenance tasks (whether in the AMOC or otherwise) in accordance with the OEM's maintenance manual instructions.

10.2 It is acknowledged that some of the tasks involved in engine continuing airworthiness may have transitioned in the AMOC package from the dedicated workshop (where these tasks were originally carried out) into the aircraft base maintenance environment. The maintenance organisation has responsibility to ensure that all staff involved in the engine maintenance activity (including the AMOC) are assessed and controlled for appropriate experience, competence and training to carry out the tasks prescribed. Whatever the task, the maintenance organisation should ensure that it has available the appropriate tooling and equipment, approved data and contamination free environment to carry out any engine maintenance operations (including those requiring partial disassembly and complex activities).

11 Safety Critical Tasks

11.1 Whenever multi-system maintenance is carried out on aircraft systems including engines, fuel etc, the Maintenance Organisation shall establish procedures to

minimise the risk of multiple errors by individual maintenance personnel during a single line or base activity (the principles of BCAR A8-23 paragraph 15.2 c) refer).

12 Engine Records

12.1 The retention of full engine records is necessary for the confidence of the continuing airworthiness programme. Therefore, the following issues should be accommodated:

a) Details of last restoration or overhaul (dates etc.) activities

b) Completion of engine operation hours and cycles in logbooks (including for ground running)

c) Strict disc, drum and shaft (i.e. critical part) life logging and controls within the framework of OEM declared lives

d) Evidence of compliance with Mandatory Permit Directives (MPDs) and Airworthiness Directives (ADs) as applicable

e) Retention of maintenance workpack details

f) Engine storage details – compliance with OEM's instructions (refer to 13.1 below for clarification)

13 Engine Storage

13.1 Installed engines which are used only infrequently should be either run periodically or routinely inhibited and stored in accordance with manufacturer's instructions or applicable military publications (e.g. AP).

13.2 Spare engines (uninstalled) should be stored and sealed in accordance with manufacturer's instructions or applicable military publications (e.g. AP).

13.3 Maintenance organisations regularly involved in the storage and inhibiting of engines should establish procedures and work sheets to ensure adherence to engine manufacturer's instructions, which include maintaining the engine storage status within the records. Engine logbooks and records should clarify the dates and extent of system inhibition/de-inhibition, providing details where relevant. These procedures should include managing removed

14 Periodic Review

14.1 Operators and CAMOs wishing to utilise the AMOC option should periodically review the effectiveness of their reliability programmes by utilising findings and feedback data as well as workshop findings/strip reports on a regular basis, as formalised under their organisation's procedures.

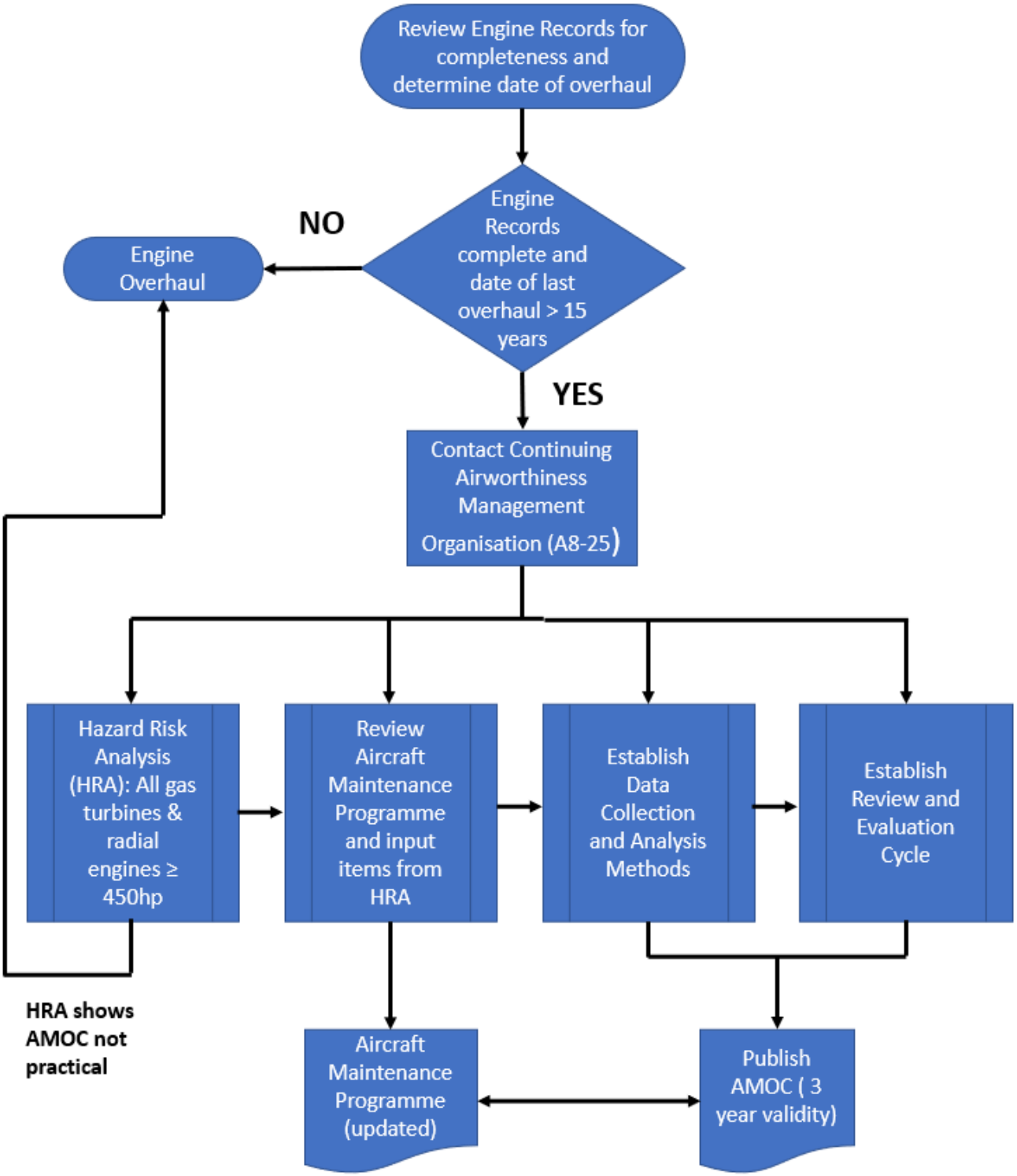
15 AMOC Management

15.1 It is the responsibility of the Continued Airworthiness Management Organisation (e.g. BCAR A8-25 or equivalent) to manage the AMOC package (under its privileges) as an alternative to a 15 year calendar life to recondition or overhaul the engine in a workshop environment, and to reflect all elements of the package within the aircraft level Maintenance Programme.

16 Mandatory Permit Directive (MPD) and Airworthiness Directive (AD) Compliance

16.1 Where the guidance information provided in this leaflet conflicts with an MPD or an AD (either already in existence or in the future) against an aircraft/engine type, the MPD/AD must still be complied with.

Appendix I: Fixed Calendar Time Overhaul and Alternative Means of Compliance Options



Appendix II: Generic AMOC inspections for gas turbine engines

Zones	Gas Turbine Engine – Inspection Type	Frequency *
Compressor Inlet	Visual inspection (where possible) of compressor inlet for signs of FOD and corrosion.	Monthly/pre-flight daily
Axial Compressor Stages as far as is practical	Borescope blades through IGV, vanes and rotor path linings of stages as far as possible, for corrosion, damage and deterioration.	3-12 Monthly
All stages of compressor	Detailed visual inspection of all compressor stages (blades, vanes and linings) with compressor top casing removed, for corrosion, damage and deterioration of blade aerofoil and blade attachment features where possible.	2-4 yearly
Combustion chamber and burners	Check for erosion, corrosion, hot spots and deterioration of all cans and burners. Check for evidence of symmetrical flame pattern, streaking and coking.	2-4 yearly
HP Turbine	Check HPT blades and vanes for erosion and heat damage, with combustor cans removed.	2-4 yearly
LP Turbine	Check LPT blades and vanes for erosion and heat damage, utilising access from the jet pipe.	3 monthly
Jet Pipe	Detailed visual inspection for damage or age- related deterioration.	3 monthly
Jet Pipe	FPI or suitable alternative NDT inspection of welded areas for signs of deterioration.	3 yearly
Bleed Valves	Visual inspection for corrosion.	6 monthly
Oil and Fuel Filter Replacement	Remove, section and analyse filter elements for evidence of contaminants – sending deposits away for analysis and plot findings where applicable.	12 monthly
Spectrometric Oil Analysis Programme	SOAP oil analysis.	6-12 monthly
Ancillary Equipment	Remove for overhaul, disassembly or bench test ancillary components (such as pumps, fuel control units, etc.).	4-6 yearly
Flexible Hoses	Inspect, replace, pressure test in accordance with OEM's recommendations. CAP 562 Book 2, Leaflet 20-50 provides some generic test details. Periodically section representative sample hose.	2-5 yearly
Power Runs	Carry out installed engine ground power assurance check	12 monthly
Engine Storage	Inhibit stored engines in accordance with OEM instructions	12 monthly

***NOTE:** The task frequencies given above are only intended as generic guidelines in the absence of any recommendations or specific inspections from the manufacturer. Furthermore, the intervals should not supersede reduced repeat inspection intervals that may be required to monitor any permitted deterioration within the approved limits of certain parts. Findings resulting from the above tasks should be documentedin the aircraft records for future reference when carrying out periodic reviews of the effectiveness of the implemented programme.

Appendix III: Generic AMOC inspections for radial piston engines

Zones	Large Radial Piston Engine - Inspection Type	Frequency *
Engine Externals	General Visual Inspection of the cylinders and crankcase including baffles for corrosion, cracking, heat distress, leaks etc.	12 monthly
Cylinder Compression Check	Compression check where applicable and in accordance with manufacturer's instructions, recording the results.	12 monthly
Cylinder Valves	Carry out cylinder valve clearance check for all cylinders.	12 monthly
Sample Cylinder Removal	Remove cylinders (where applicable) from each bank plus other sample cylinders (alternating at each maintenance opportunity where possible) and carry out detailed visual inspection of internal cylinder bore and components such as pistons, connecting rod assemblies, gudgeon pin internal bores for evidence of wear and age related deterioration.	6 yearly
Internal Crankcase	Check internal crankcase for evidence of oil sludge and moisture.	6 yearly
Cylinder Borescope	Carry out internal borescope inspection of each cylinder via spark plug hole, recording and assessing the condition of valves, piston crown, cylinder head and cylinder walls.	12 monthly
Engine Oil Condition	Send sample of engine oil for SOAP oil analysis Remove, inspect and clean oil sump plugs and oil screens as applicable.	12 monthly
Engine Filters/ Screens	Replace, section and examine fuel and oil filter elements where applicable for evidence of debris. Collect filter debris for inspection, analysis and future reference.	12 monthly
Power Runs	Carry out installed engine ground power assurance check.	12 monthly
Ancillary Equipment	Remove for overhaul, disassembly and bench test ancillary components (such as magnetos, carburettors, pumps, control units etc).	4-6 yearly
Crankshaft/ Reduction Gear Assembly	Carry out in-situ inspection of crankshaft/reduction gear assembly for signs of corrosion, cracking deterioration (e.g. along propeller attachment splines), viewing as much of the crankshaft as is accessible or possible.	3-6 yearly or at propeller removal opportunity (whichever is soonest)
Flexible Hoses	Inspect, replace, pressure test in accordance with OEM's recommendations. CAP 562 Book 2, Leaflet 20-50 provides some generic test details. Periodically section representative sample hose.	2-5 yearly
Cylinder base nut check	Break torque check on cylinder bolts, to ensure bolts are not backing off.	3 yearly
Engine Storage	Inhibit stored engines in accordance with OEM instructions	12 monthly

***NOTE:** The task frequencies given above are only intended as generic guidelines in the absence of any recommendations or specific inspections from the manufacturer. Furthermore, the intervals should not supersede reduced repeat inspection intervals that may be required to monitor any permitted deterioration within the approved limits of certain parts. Findings resulting from the above tasks should be documented in the aircraft records for future reference when carrying out periodic reviews of the effectiveness of the implemented programme.