General Aviation Unit

Ex-Military Aircraft

Design, restoration and continuing airworthiness approval

CAP 1640

Published by the Civil Aviation Authority, 2021

Civil Aviation Authority
Aviation House
Beehive Ring Road
Crawley
West Sussex
RH6 0YR

First published 2018
Issue 2 published 2021

Enquiries regarding the content of this publication should be addressed to: GA@caa.co.uk

The latest version of this document is available in electronic format at: www.caa.co.uk

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Summary of revisions in issue 2

This document has been revised since the initial issue. The following sets out the broad topics that have been subject to major amendments. This does not reflect small textural alterations such as gramatical or word substitutions that have no technical effect.

Paragraph	Topic	Revision made
Foreword	Scope and applicability of publication	Scope broadened from just Permit to Fly, to CAA airworthiness approval of ex-military aircraft. Addition of reference to Regulation (EU) 2018/1139 Annex 1 and amendment to hyperlink.
1.9	Ex military aircraft eligible for a certificate of airworthiness	New paragraph introduced to clarify that some ex-military aircraft are eligible for a certificate of airworthiness and that the general guidance herein can apply.
1.27-1.28	Scope of A8-25 Supp 2 and A8-21 authorisations	Clarification of the A8-25 Supp 2 signatory role and that provided by an A8-21 design organisation.
1.37 Introduction	DESA disposal process	DESA criteria for disposal added
1.39	Ex-military complexity classification	Minor clarification of the process undertaken by CAA in classifying the complexity of an ex-military aircraft.
2.1c.	Design definition material	Clarification of data expected by CAA to support an application.
2.10-2.17	Aircraft identity and provenance	Clarification of process undertaken by CAA in investigating an aircraft registration application and its original identity.
2.24 and 2.26	Replica aircraft	Minor clarification of modification classification and approval process.
3.5-3.10, 3.13-3.14	Complexity classifications	Enhanced clarification of the complexity classifications and the process undertaken to define each case.
4.3-4.4	Modifications	Modification classification process clarified in accordance with A8-21 Appendix 2
4.10 and 4.13	Modification guidance	Reference to CAP1419 and CS-STAN applicability for Annex 1 aircraft.

Paragraph	Topic	Revision made
		Clarification of use of supporting modification data
5.38	CAP747 GR Reference	Removal of specific reference to amendment to GR24 that will be addressed through the appropriate revision cycle.
5.40-5.41	Ageing wiring guidance	Introduction to independent review of the condition of wire and wiring materials found in British ex-military aircraft.
6.13	Safety Standards Acknowledgement and Consent	Reference to CAP 1395 and clarification of airworthiness considerations for intermediate type SSAC operations.
A-1.3.3	Airworthiness Approval Note	Clarification that AAN is record of CAA investigation.
A-1.21	Flight test	Clarification of selection of pilot and test schedule selection.
A-3.3.1	Pyrotechnics	Need for communication of data added
A-3.5.1-A-3.5.8	Aircraft occupancy	Clarification of current occupancy policy and means to increase occupancy, with objectives.
A-3.21.1	Flight in IMC	Clarification that limitations alteration will require Major Modification action.
A-3.22.1	Hazardous Materials	Need for communication of data added
A-4.2.1 h)	A8-25 procedures	Additional clarification text on complex aircraft continued airworthiness support
A-5.1.2	Changes to the original design	Clarification that all changes require modification action
A-6.2.3 and Appendix 7	Electrical Wiring	Permitted publication of Airwire report on the condition of wire and wiring materials found in British ex-military aircraft, built in the World War II and Post-war period, (for Permit to Fly).
A6-2.5	Seat Harnesses	Reference added to guidance published by CAA

Foreword

This publication provides guidance for those who are seeking to obtain a CAA Airworthiness approval for an ex-military aircraft, or who wish to restore, maintain and operate such an aircraft on the UK Civil register. This guidance material, over and above that provided in the statutory requirements, is based on experience gained from past approvals. Unless otherwise stated, nothing in this publication is intended to conflict with the Air Navigation Order, British Civil Airworthiness Requirements or other legislation which, for the avoidance of doubt, **must** be regarded as overriding. Compliance with this publication does not by itself indemnify any person or persons against liability for an accident or serious incident occurring. Whilst every effort is made to ensure that all information is correct at the time of publication, the CAA reserves the right to amend this document as required to accommodate changes to the law, to correct errors and omissions, or to reflect changes in national policy and good practise. It is generally assumed to be applicable to aircraft that have not been designed and manufactured to specified civil standards and are ineligible for the issue of a Certificate of Airworthiness, but it is acknowledged that there are a few aircraft that have both seen military service but also have civil Type Certificates

The Convention on International Civil Aviation signed in Chicago on 7 December 1944 requires aircraft registered in Contracting States to be provided with a Certificate of Airworthiness for international flight. The United Kingdom, which is a Contracting State to the International Civil Aviation Organisation (ICAO), has undertaken to implement national regulations that are, wherever possible, compliant with the ICAO standards. The Civil Aviation Authority (CAA), which acts on behalf of the British Government by virtue of the powers delegated to it under the Civil Aviation Act, develops and administers the UK regulations.

The primary national regulations relating to the airworthiness of aircraft are contained in the Air Navigation Order 2016 (ANO) Part III where it is stated that all aircraft operating in UK airspace shall have a valid Certificate of Airworthiness, but that if a British registered aircraft is unable to satisfy the requirements for the issue of a Certificate of Airworthiness, it may, instead, be issued with a United Kingdom Permit to Fly (PtF).

The Permit to Fly contains additional operational restrictions on the use of the aircraft and does not satisfy the requirements for international flight. Due to this limitation, British registered aircraft with a UK Permit to Fly require permission to fly within the airspace of another country. Similarly, foreign registered aircraft operating on airworthiness documents which are not ICAO compliant will also require the permission of the CAA to fly within UK airspace. Guidance on the principles that should be applied in the case of any application for a Permit to Fly is contained in the British Civil Airworthiness Requirements (BCARs). In particular, BCAR Section A Chapter A3-7 deals with design and construction standards and Chapters A8-23, 24 and 25 are concerned with the maintenance and continuing airworthiness management of ex-military aircraft.

The European Aviation Safety Agency (EASA) became operational on the 28th September 2003 and assumed many of the functions previously undertaken by the National Aviation Authorities (NAAs) of the EU Member Nations. Many of the aircraft which fly on a UK Permit to Fly were excluded from regulation by EASA, by Regulation (EU) 2018/1139 Annex I (which superseded Annex II to EU Regulation (EC) No. 216/2008), which is the legislation enabling the formation of EASA. Such excluded aircraft remained subject to national requirements. In essence, this meant that any such aircraft which had been flying on a Permit to Fly will continue to require a Permit to Fly issued by the CAA under the ANO. Note that the UK’s withdrawal from EU and from at least full membership of EASA has not changed the status of these UK-cleared ex-military aircraft.

Glossary

AAN	Airworthiness Approval Note
AD	Airworthiness Directive
AAIB	Air Accident Investigation Branch
ANO	Air Navigation Order
AP	Aviation Publication
ARB	Airworthiness Requirements Board
ASI	Air Speed Indicator
AVGAS	Aviation Gasoline
BCAR	British Civil Airworthiness Requirements
CAA	The Civil Aviation Authority
CAAIP	Civil Aircraft Airworthiness Information and Procedures
CAMO	Continuing Airworthiness Maintenance Organisation
CAP	Civil Aviation Publication
CARS	Civil Aviation Regulations (Canada)
CASA	Australian Civil Aviation and Safety Authority
CASR	Civil Aviation Safety Regulations (Australia)
CG	Centre of Gravity
CofA	Certificate of Airworthiness
CofV	Certificate of Validity
DAP	CAA Directorate of Airspace Policy
DESA	UK MoD Defence Equipment Sales Agency
DLS	CAA Design Liaison Surveyor
DOA	Design Organisation Approval
EASA	European Aviation Safety Agency
EFIS	Electronic Flight Instrument System
FAA	United States Federal Aviation Administration
FADEC	Full Authority Digital Engine Control

FAR	Federal Aviation Regulation
FBW	Fly By Wire
FI	Fatigue Index
FM	Flight Manual
FRC	Flight Reference Cards
GAU	General Aviation Unit
GR	Generic Requirement
HP	Horsepower
HUD	Head Up Display
ICAO	International Civil Aviation Organisation
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
LAA	Light Aircraft Association
LAMS	Light Aircraft Maintenance Schedule
LTC	Limited Type Certificate (US)
MAA	Military Aviation Authority (UK)
MDC	Mini-Detonation Cord
MOD	UK Ministry of Defence
MPD	Mandatory Permit Directive
MSN	Manufacturer’s Serial Number
MTMA	Maximum Take-Off Mass Authorised
MTWA	Maximum Take-Off Weight Authorised
NAA	National Aviation Authority
NATO	North Atlantic Treaty Organisation
NDI	Non-Destructive Inspection
NDT	Non-Destructive Test
NZCAA	New Zealand Civil Aviation Authority
OEM	Original Equipment Manufacturer
OCM	Organisational Control Manual

PFRC	Permit Flight Release Certificate
PMA	Parts Manufacturing Authorisation
PMR	Permit Maintenance Release
POH	Pilot’s Operating Handbook
PtF	Permit to Fly
RAF	Royal Air Force
RO	CAA Regional Office
SB	Service Bulletin
SoD	State of Design
SoR	State of Registry
SSAC	Safety Standards Acknowledgement and Consent
STI	Special Technical Instruction
TCA	Transport Canada – Air
TC	Type Certificate
TCDS	Type Certificate Data Sheet
TCH	Type Certificate Holder
TP	Test Pilot
TRA	Type Responsibility Agreement
USAF	United States Air Force
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

Chapter 1 Introduction

1.1 The CAA continues to support the scale of restoration of ex-military aircraft that has developed over the last fifty years or more. However, such restoration must be managed throughout the life of the project in an appropriate manner that ensures that results in an airworthy product, that is properly defined, and compliant with the relevant requirements.

1.2 The restoration of ex-military aircraft varies considerably from the transition of a just out of service aircraft into the civil environment to a more substantial recovery of a severely damaged World War II aircraft, complete with bullet holes, fire damage and corrosion. Accordingly, the aircraft will have different demands to ensure that airworthiness is achieved to allow a Permit to Fly to be issued. As such, each ex-military aircraft is regarded as being unique. Whilst a number of the type may have qualified for a Permit to Fly, the circumstances surrounding the nature of the individual aircraft's history requires separate consideration. Each aircraft therefore has its own Airworthiness Approval Note (AAN) covering the history, any work done on transition to the civil system and the conditions associated with the issue of the Permit.

1.3 This CAP has arisen from a review of relevant material, both in the UK and overseas, in the wide context of the approval of Permit to Fly aircraft and, in particular those of military origin that have not previously been type certificated. This is a summation of the methods by which CAA will approve such aircraft and brings together all available information regarding restoration, maintenance and operation of ex-military aircraft. It is intended that the CAP will be a dynamic document that can be updated on a regular basis to take account of latest practices and information available.

1.4 This CAP takes into account, where possible, how other similar civil aviation authorities with such fleets go about their approval processes, in order to arrive at a coherent, transparent guidance document that facilitates the approval of ex-military aircraft. It is therefore intended that this CAP will give clear guidance both to applicants and CAA Surveyors as to the expectations from submission to approval. It aims to make clear the roles and responsibilities placed on the design, maintenance and continuing airworthiness management organisations and of the expectations of CAA Surveyors. This should allow the most expedient route to approval whilst maintaining appropriate levels of CAA oversight.

1.5 Additionally, this CAP contains guidance on standards parts, standard modifications and flight test approvals.

Purpose and scope

1.6 Within the United Kingdom, the operation of aircraft and the conduct of associated aviation activities are governed by the various legislative requirements contained in the United Kingdom Air Navigation Order 2016 (ANO). This requires that, except when operating in accordance with the provisions contained in Articles 24(3), 33(2), 40, 41 and Schedule 4 of the ANO, an aircraft must be registered and have a valid Certificate of Airworthiness issued by the State of Registry. The CAA is responsible for the airworthiness of aircraft that are on the British register and requires compliance with the standards and detailed requirements contained in the British Civil Airworthiness Requirements (BCARs) together with those carried across from European (EASA) as well as International (ICAO) Regulations as appropriate.

1.7 An aircraft will normally be issued with a Certificate of Airworthiness by its ‘State of Registry’, and this document attests to that National Aviation Authority being satisfied with the design and workmanship and the materials used in the construction of the aircraft. After a ‘State of Design’ has investigated all aspects of an aircraft’s design, construction and flight characteristics, it will issue a ‘type certificate’, and it is compliance with this document that forms the basis on which individual Certificates of Airworthiness will subsequently be issued.

1.8 There are many aircraft, including the majority of aircraft of military design and service, which are not able to qualify for the issue of a Certificate of Airworthiness. In such cases, the CAA may when satisfied issue a Permit to Fly which confirms that an aircraft is safe to fly, considering its overall design, construction and maintenance, but not to the extent provided for by the level of assurance that an aircraft with a Type Certificate and Certificate of Airworthiness could achieve. Due to this reduced level of airworthiness assurance, to ensure that an acceptable level of safety is maintained, additional limitations and conditions may be placed upon the operation of these aircraft.

1.9 A small number of aircraft types of military design and service are eligible for a Certificate of Airworthiness. In these cases, the type is either supported by organisations taking the role and responsibility of Type Certificate holder or it has a formally published Type Certificate (TC). These aircraft can therefore be operated with fewer restrictions than ex-military Permit to Fly aircraft. In accordance with the Air Navigation Order 2016, Article 40 (2) the aircraft will be issued with a Certificate of Airworthiness, rather than a Permit to Fly and be considered compliant with ICAO Annex 8. Such aircraft include the Boeing Stearman and the Consolidated PBY-5A. Similarly, some aircraft of UK design are supported by an organisation holding a Type Responsibility Agreement with the CAA, taking some or all of the continued airworthiness responsibilities of a Type Certificate holder, to the extent that such aircraft of military design and service may also be eligible for a National Certificate of Airworthiness. Whilst the purposes and content of this report is to address the Permit to Fly approach for aircraft of military design and service, some aspects of the approach will apply to those eligible for a National Certificate of Airworthiness because of their military design and service origins. CAA should be consulted as to which route a particular aircraft is required to take.

1.10 An individual aircraft of military design and service may qualify for the initial issue of a Permit to Fly if the following are addressed to the satisfaction of the CAA:

1.11 The aircraft conforms to a design that was accepted by the recognised national authority of the state of design to fly within defined limitations.

1.12 The aircraft type has/had accumulated sufficient evidence of safe operation to demonstrate that such aircraft are safe to fly subject to whatever conditions may be appropriate.

1.13 An assessment of the aircraft demonstrates that any features with potentially unsafe failure modes are sufficiently reliable.

1.14 Manuals and procedures approved for the aircraft's military service are available.

1.15 A Through-Life-Total-Support approach is implemented. A Through-Life-Total-Support approach will require the applicant to consider the implications of differences in the operation and maintenance environment of the proposed Permit to Fly operation compared to that of the original national (military or aviation) authority authorised operation, and be able to justify that the implementation achieves an appropriate ongoing level of safety.

1.16 The applicant demonstrates that the aircraft complies with the requirements of the relevant aircraft classification of BCAR A8-25 Supplement 2 that are broadly defined as Simple, Intermediate or Complex, and demonstrates that all of the objectives required by its classification are satisfied.

1.17 Notwithstanding the content of the ANO and BCAR A3-7, the aircraft of military design and service may continue to qualify for the Permit to Fly if all of the above conditions remain valid and the subsequent civil-registry service safety record has continued to demonstrate that the aircraft is safe to fly, subject to the original or amended limitations.

Issue and revalidation of a permit to Fly

1.18 Although a Permit to Fly is often thought of as embodying a lesser standard of airworthiness than a Certificate of Airworthiness, a Permit to Fly will only be issued on the basis that the aircraft to which it relates is airworthy. Under the provisions of the ANO, ex-military aircraft, which are eligible for the issue of a Certificate of Airworthiness, or are the subject of 'Type Certification' in another state, will not be eligible for the issue of a Permit to Fly. This means that a Permit to Fly will normally only be issued to ex-military aircraft which are not eligible to hold Certificates of Airworthiness because they have either never been type certificated or the type certificate holder has withdrawn its support for the aircraft type.

1.19 A Permit to Fly will only be issued after the CAA has investigated the aircraft. This investigation will cover those elements necessary to make sure that the aircraft is fit to fly and has no adverse operating or handling characteristics. When issued, the Permit to Fly will be non-expiring and will be revalidated by a Certificate of Validity, which will be conditional upon the completion of the periodic maintenance, inspections and checks. The actual process of Permit issue and revalidation varies according to aircraft type, the conditions under which the individual aircraft operate and the privileges of the associated approved organisation.

Permits to Fly and approved organisations

1.20 Before a Permit to Fly can be issued, the build standard, history and the intended operational use of the aircraft will be investigated. This process remains consistent irrespective of the basis upon which the application for a Permit to Fly is to be made.

1.21 The CAA has developed a number of different processes to deal with the specific needs of the industry, which reflect the varying nature of operations and the classifications of the various types of aircraft that may be eligible for a Permit to Fly.

1.22 Depending on the class and weight of an aircraft, the CAA may require the ex-military aircraft to be maintained and supported by organisations that have been approved according to BCAR Section A, Chapter A8-23 or 24 and 25 as appropriate. In the main this is for those fixed wing aircraft above 2,730 kg and helicopters, or where the CAA believes this will assist or progress the application. However, these BCAR A approvals are equally relevant to other ex-military aircraft if applicable.

1.23 The initial Permit to Fly and Certificate of Validity will be issued by the CAA following the submission of design reports by the organisations approved under BCAR A8-25 (as applicable) and after a survey conducted by the CAA. Full Permit issue will follow flight tests taken place under a Permit to Test issued against a Working Draft of the AAN – see Appendix 1. Subsequent Certificates of Validity will be issued following recommendations for revalidation by the relevant BCAR A8-25 approved organisation (as applicable). Aircraft which are not maintained under the control of an approved organisation will be investigated and surveyed directly by the CAA for the purpose of issuing a Permit to Fly, and the associated Certificates of Validity will be issued or re-issued subject to periodic and satisfactory inspection by the CAA.

1.24 There is also scope to cater for organisation approval privileges that will allow revalidation of a Permit to Fly without the CAA's direct involvement. This follows the CAA's drive to put such activity within the capability of approved organisations, allowing the CAA to concentrate its resources on the oversight of the organisations and the proportionate risk.

BCAR A8-23, A8-24 and A8-25 Approvals

1.25 The current requirements for the airworthiness support of ex-military aircraft are generally contained in BCAR A8-23, A8-24 and 25. These approvals replace the previous two main sub-elements of BCAR A8-20, E4 and M5 with those being subsumed and built upon. The requirements initially applied to aircraft above 2730 kg MTOW but, in order to provide greater flexibility for companies to manage their aircraft below that weight limit, the requirement was amended to cover any weight aircraft.

1.26 When BCAR A8-20 was introduced, the CAA included provision for the organisation to assist in defining the aircraft configuration. This organisation would review the build standard of the aircraft in relation to the original military standard and record the differences from that standard. The organisation catalogued the conformity of this build standard, the modification standard and the maintenance history, and the operational history of the type in order to provide a report from which the CAA could draft the Airworthiness Approval Note (AAN) that would support Permit to Fly issue.

1.27 In general, this worked well but there appeared to have been some confusion as to what the E4 element of the approval represented. This is now clarified by the transfer of the E4 element to BCAR A8-25 Supplement 2. This allows the organisation to investigate and compile a substantiation report on the aircraft, its history, build standard, modifications, equipment fit to help the CAA draft the AAN that will eventually clear the aircraft for Permit issue. This is not a design approval and confers no privileges in respect of the approval of modifications or changes at any level (see BCAR A2-5). That said, an AD458 authorisation is expected to be held by the individual responsible for submitting the substantiation reports from an A8-25 Supplement 2 organisation and that these individuals will possess sufficient knowledge and experience of the chosen aircraft's design and modification standard that the report is both authoritative and sufficiently detailed to provide a sound basis for the application.

1.28 There are a number of existing BCAR A8-21 companies that currently work on ex-military aircraft to support design activity, such as modification and repair justification. Whilst applications for minor changes/repair approvals can be submitted directly to CAA for consideration, such companies should normally be used by A8-25 organisations to cover design activity, and certainly any categorised as major.

1.29 The move towards a system where all non-expiring Permits could be revalidated through an approved organisation utilises the A8-25 approval to support the process to advantage. This approval has been developed into a CAMO arrangement such that there is a situation that better supports continuing airworthiness management processes. This is as important for Permit aircraft as it is for those with a CofA. By changing the design report element, it provides greater clarity of function, introduces provision to give industry a CAMO style capability and allows CAA to reduce its direct involvement in processes that can be adequately managed by approved organisations with appropriate CAA oversight.

1.30 The other aspect is the A8-23 and A8-24 approval. These provide catch all approvals covering a variety of different processes under their umbrellas. These include the normal activities associated with maintenance but more importantly for this sector it permits considerable (in some cases total) restoration of unairworthy projects. However, it ought to be recognised that there is a considerable difference between routine support and a total rebuild.

1.31 These approvals provide for maintenance of the aircraft and the scope of approval will normally relate to specific aircraft types. The previous A8-20 M5 approval did not provide any commercial manufacturing capability and the parts could not be sold onto third parties therefore the manufacture of parts or components to support ex-military restorations for other organisations required a further approval, such as that currently available under BCAR A8-2 or A8-21. It is noted that the provisions of A8-21 were not written with Permit to Fly aircraft in mind and therefore the requirements may be seen as being over-burdensome when applied to ex-military aircraft support organisations.

1.32 A8-23 and A8-24 allow maintenance, overhaul, repair and restoration but introduce limited scope such that fabrication can take place. The need to exercise sub-contract control over external support arrangements with unapproved organisations is strengthened and an additional rating under A8-23/24 has been developed to cover the fabrication activity, thereby negating the need to hold separate approvals in all cases. This is further explained in Chapter 4 and Appendix 5.

1.33 There is no reason why BCAR A8-23/24 cannot be used for the purposes of performing maintenance on engines, propellers or equipment for ex-military aircraft. It is relatively straightforward to build in a capability to cover these ancillary tasks to allow these to be covered separately from a complete aircraft approval. This provides for a greater degree of flexibility.

1.34 For ex-military aircraft revalidation shall be recommended by an appropriately approved organisation, e.g. to BCAR A8-25. The revalidation process will, normally, involve maintenance inspections and test flying to ensure that the aircraft is still able to meet the requirements of the Permit.

1.35 Once expired, the Certificate of Validity must be renewed before further flying is carried out. However, where necessary a Permit to Fly for test purposes may be issued, or the aircraft may be flown on ‘A’ or ‘B’ conditions under the control of an organisation suitably approved by the CAA for that purpose.

Limitations of use of a Permit to Fly aircraft

1.36 In recognition of the lack of compliance with some of the standards of airworthiness, the issue and continued validity of a Permit to Fly will reflect the limitations under which an aircraft is permitted to operate and will normally be more restrictive than the operating conditions permitted in the case of a comparable aircraft operating on a Certificate of Airworthiness. Examples of limitations are as follows:

a. An aircraft flying in accordance with a permit to fly may only be flown by day and in accordance with the Visual Meteorological Conditions unless the prior permission of the CAA has been obtained.

b. Limitations may be placed upon the numbers of persons permitted to be carried in the aircraft, either in general, or in specific operational circumstances.

c. Aircraft will be required to be placarded showing operating limitations and conditions.

d. Aircraft will normally be restricted to flights within UK airspace unless the prior agreement of the country in which the flights are to be made is obtained.

e. Aircraft will not normally be permitted to fly over congested areas.

Eligibility of Ex-military aircraft

If an aircraft is of military origin and is not eligible for a Certificate of Airworthiness, the CAA may consider an application for a Permit to Fly. Note the word ‘may’ here is important, as unlike with an aircraft able to qualify for a Certificate of Airworthiness, the decision as to whether an aircraft is acceptable for a Permit to Fly is at the discretion of the CAA. Nowadays in the UK, sales of ex-military aircraft into the private sector are conducted by the Ministry of Defence, Defence Equipment Sales Authority (DESA), or its nominated agent, Agility. The DESA or Agility Sales Agreement will generally state that the aircraft is being sold on the basis that it cannot be returned to flight unless it has the support of the OEM, or its nominated agent. Such a stipulation will naturally have a bearing on any subsequent application for a Permit. The CAA are likely to discuss such sales with DESA as part of the initial consideration as to whether a Permit application is appropriate. Such discussions are likely to include a continuation of OEM support, whether the proposed civil organisation has the required funding and to what extent it would need to present a risk mitigation case, even whether there is an argument for net benefit such as educational /STEM aspects.

1.37 Aeroplanes of greater than 2,730 kg MTWA, and rotorcraft of any weight, will be required to be supported by a maintenance organisation approved under BCAR Section A, Chapter A8-23 or A8-24. Aeroplanes of 2,730 kg MTWA or below will not normally require the involvement of a BCAR A8-23/24 maintenance organisation.

1.38 Ex-military aircraft have often been designed to requirements that differ substantially from those of civil aircraft. Consequently, the design review of an ex-military aircraft will consider associated issues such as the operational role of the aircraft and the accident record. If, on the basis of this evidence, the CAA is satisfied that the aircraft is fit to fly, it may be granted a Permit to Fly.

1.39 Ex-military aircraft will be classified by the CAA as ‘simple’ (e.g. Auster AOP-9, Harvard, Hurricane or P-51), ‘intermediate’ (e.g. Grumman F7F, de Havilland Vampire or Westland Wasp) or ‘complex’ (e.g. Buccaneer, Harrier and Vulcan) according to the definitions shown in BCAR Section A, Chapter A8-25 Supplement 2. These classifications reflect a number of aspects including, but not limited to the complexity and reliability of the technology employed in both the aircraft and required operational and support equipment, but also the implications of critical systems failures, all of which have an effect on the degree of airworthiness that is likely to become evident during civil service. The more complex an aircraft is, the greater the level of organisational and operational support that will be required and, unless the CAA agrees alternative provision through a suitably competent design organisation, the continued involvement of the manufacturer will be required. Further guidance on how the CAA determines complexity is given in Chapter 3.

1.40 The CAA will issue Permits to Fly for ex-military aircraft after consideration of the recommendations and inspection reports submitted by the relevant BCAR A8-25 organisations and will liaise with the BCAR A8-25 organisations concerning the detail, form and content of the inspections to be undertaken for this purpose.

1.41 In the case of ex-military aeroplanes of 2,730 kg MTWA or below, the CAA may interface directly with the applicant. The applicant will be expected to provide the CAA with sufficient information for development of an Airworthiness Approval Note (AAN) to record the basis upon which a Permit to Fly can be issued. The CAA may then, following the conduct of a satisfactory survey and investigation, and a satisfactory test-flight, issue a Permit to Fly.

Ineligible aircraft

1.42 Aircraft which are eligible for the grant of a Certificate of Airworthiness will be required to comply with the appropriate internationally recognised standards and will not normally be considered for the issue of the United Kingdom Permit to Fly. This includes all series-built aircraft that have been built for civil use. It should be noted that an acceptance by another National Authority of an aircraft, without a Certificate of Airworthiness, to fly on a permit does not constitute a right for that aircraft to qualify for a UK Permit to Fly.

1.43 Aircraft may also be ineligible for other reasons, such as an unacceptable safety record.

Chapter 2 Qualifying for the Initial Issue of a Permit to Fly

General

2.1 The process associated with the issue of a Permit to Fly follows the same basic steps irrespective of the aircraft type, whether it is dealt with directly by the CAA, or by an approved organisation. The details are contained in BCAR Section A, Chapter A3-7 (or in BCAR Section B, Chapter B3-7 for foreign products) and include the following requirements:

a. The aircraft must be UK registered.

b. An application for a Permit to Fly must be made

c. The need to provide design definition material to justify the airworthiness approval (by AAN) necessary to support a Permit to Fly application. This should include reports that the aircraft is in conformance to a suitable design standard and any changes from this standard have been approved in accordance with BCAR A2-5 or B2-5.

d. The aircraft design standard must have been adequately reviewed and documented.

e. The standard of restoration, maintenance, repair and overhaul must achieve an airworthy condition to ensure that the aircraft is fit to fly.

f. The aircraft must be inspected at various stages during its restoration.

g. The need for the owner/Maintenance Organisation to generate a visit programme for both Airworthiness Surveyor and Design Surveyor as appropriate

h. The need for comprehensive records of the project on an ongoing basis

i. The method by which the organisation has assured itself of how it has sourced all of the available data to carry out a restoration project and how it handles the parts, particularly if the owner provides parts

j. The aircraft must be test-flown to an agreed schedule.

k. The aircraft build standard, modification records, maintenance record and operating history shall be available.

2.2 A Permit to Fly will not be issued to an aircraft which has formerly been issued with a Certificate of Airworthiness by an ICAO contracting state, unless it is no longer possible to fulfil the requirements for the issue of a Certificate of Airworthiness.

2.3 Guidance on when a former CofA aircraft may be eligible for a Permit to Fly is given at: http://www.caa.co.uk/General-aviation/Aircraft-ownership-and-maintenance/Types-of-aircraft/Orphan-Aircraft/

Major Restoration Projects

2.4 The recovery of a severely corroded airframe, or part of one, can often act as the initiation point for restoration of an aircraft that requires rebuild virtually from first principles. This is therefore taken as the worst-case scenario. It is recognised that the restoration will often be performed within a BCAR A8-21, A8-23, A8-24 and/or A8-25 approved organisation. This means that the organisation will have demonstrated an overall competence in ex-military aircraft maintenance that will allow the CAA to take a degree of confidence that the project will be managed appropriately.

2.5 In many cases, the availability of replacement parts is severely restricted, particularly with regard to structural components. The solution often therefore requires manufacture of replacement parts to drawings that may be available, or by reverse engineering. This introduces issues of material substitution, as many of the original specification materials may no longer be available. It is important therefore that the restoration is project managed around a defined progressive programme of decisions and activities. To this end, the work can be substantiated and the decisions on alternative manufacture or materials can be seen and demonstrated.

2.6 If the approval is not held in house, the support of an appropriately approved BCAR A8-21 design organisation will be needed to substantiate decisions that have not already been the subject of modification action. This is important, as material substitutions will often require careful consideration with regards to all aspects of the intended use of the material. The cataloguing of changes and their approval is also required to allow a proper aircraft design standard to be determined for Permit issue. This means that the work has to result in a progressive picture of what is being done, why and how it is substantiated and approved as the project proceeds.

2.7 It is most practical to develop communication pathways with the CAA during such extensive rebuilds to ensure that agreement on the actions being taken is given. Too often, the CAA is presented a fait accompli with aircraft where the substantiation for the changes performed is not available, leading to repetition of the work and disputes. Keeping the CAA informed periodically, or consulting on key decisions will help ensure that there is no ambiguity over the project’s status. The lack of CAA involvement at the appropriate time could also lead to the aircraft having to be dismantled to some extent to allow structural surveys of modifications or repairs to be reviewed.

2.8 It is inevitable that with ground up restorations, parts and sub-assemblies will be bought in from sub-contract organisations. It is crucial that the organisation demonstrates its oversight of these sub-contractors and its rigour in this can be demonstrated to the CAA. This will ensure that the organisation is certain of acceptability of the items it receives and that they can be accepted by CAA for use on the restored aircraft. This is usually controlled through the A8-21/23/24/25's own procedures for sub-contractor control.

Aircraft Identity and Provenance

2.9 Inspection of the project: There is no set threshold minimum for the amount of original material needed for the aircraft to be considered genuine, but there must be something recognisable and tangible as the start material. To ascertain whether or not sufficient material exists, the aircraft will need to be inspected. It should be anticipated that as a minimum, primary structure is available – generally, although not exclusively, from the fuselage – to establish a viable start point.

2.10 Ideally, where possible, the applicant would have the majority of what would be considered as the 'core' of the original aircraft, i.e. the area that would encompass the cockpit and main wing-mounting structure. Not having this structure wouldn't prohibit a project to be accepted, though it would be expected that any reason for its absence be documented so far as reasonably practicable.

2.11 Application should be made as early as possible in the restoration process for the aircraft to be registered on the UK G-Register, so that the CAA Design Surveyor and Airworthiness Surveyor can view and assess the project. This will allow CAA assurance that there is a sufficient provenance case for the restoration to be treated as original rather than a replica, even if subsequently further parts are replaced or fitted in order to make the aircraft airworthy. If it is deemed that there is insufficient material, or the provenance of the aircraft is not clear for the aircraft to be treated as original, then it may have to be declared as a replica.

2.12 After application to register the aircraft, a CAA Design Surveyor will make contact to determine the provenance of the aircraft.

2.13 A procedure has been created with a view to standardise the approach applied to these sorts of applications. The approach seeks to apply a proportionate level of scrutiny to inventories, based upon whether the inventory consists of a relatively complete aircraft with obvious evidence of the identity, or more minimal or substantially damaged/fragmented inventories. For more minimal inventories, it is expected that the reason for such a minimal inventory is clearly documented as there could be a valid reason for this e.g. high energy impact, post-crash fire, etc.

2.14 Such mechanisms to allow for more 'marginal' inventories do not subvert the requirement for the identity to be sufficiently evidenced through a combination of data plates, markings on the inventory or documented records of the aircraft (such as wreckage locations, damage reports, MOD records etc.)

2.15 This approach puts the onus the applicant to satisfy themselves of the provenance of the aircraft or inventory and in turn, for the applicant, to demonstrate the provenance to the satisfaction of the CAA.

2.16 Credit can be given to support for applications made under the auspices of an A8-25 Supplement 2 organisation approval

2.17 The decision on whether to accept a restoration project with a specific identity is made only with the evidence presented at the time of application. If information later arises that may invalidate or alter the assumptions that the decision was based upon, then it may be re-visited at a later date.

2.18 Upon successful registration, an application should be made to the UK CAA for an Initial Issue of a Permit to Fly so that sufficient oversight and staged inspections can be catered for in the restoration process.

2.19 Data plates: Most, although not all, aircraft have a data plate fitted that records certain manufacturers information including the Manufacturers Serial Number (MSN). This data plate information should be used to lend weight to the provenance of the aircraft being restored. The existence and validity of the data plate can be an important part of establishing the correct identity of the aircraft. Where the data plate is no longer in existence, reliance may be placed on the evidence of historians and published information to gain confidence in the identity of the airframe.

2.20 Conversely, some early types originating before the Second World War (such as early Hawker biplanes) did not have data plates. In such cases assessment of the remains is usually sufficient to gain satisfaction that the aircraft is genuine. Additionally, where the original data plate is not available it is permissible for the aircraft restoration company to manufacture a replacement data plate. This data plate should include the aircraft serial number and manufacturer's name. The use of a replacement data plate should be included in the aircraft records. In cases where an original data plate was not fitted the CAA will verify that it has not previously approved another aircraft as a restoration from the same wreckage.

2.21 MSN vs. Military Serial: The aircraft should be identified by its Manufacturers Serial Number (MSN) as this is a constant that remains with the aircraft throughout its life. The applicant should always attempt to identify this. Ex-military aircraft are also often referred to by their military serial (e.g. XL598) and this is sometimes employed to identify them in favour of fuselage serial numbers.

2.22 The manufacturers serial number identity is the preferred identifier as the military serial numbers applied to the aircraft may change (for example on export to another country). However, it is recognised that in some instances the MSN and the Serial Number are the same. For a limited number of aircraft, there is no record of the original MSN (for example some Spitfires built under sub-contract had the initial RAF serial applied as an MSN on the data plate). In these instances, the initial serial should be used as the identifier. This will not be acceptable where it is known that there is a definitive MSN to Serial tie-up.

2.23 Donor airframes: In some countries where re-use of the same registration is possible, further use of the registration may occur but on further example(s) of the same type, for example where the original has been written off. This could lead to a situation where effectively a donor aircraft is used in its entirety with only the registration paperwork remaining of the original aircraft. This is not acceptable to the UK CAA and genuine provenance of the actual aircraft will have to be demonstrated and recorded in the Applicant’s design report submission.

2.24 However, provided that there is no conflict with the aircraft it is painted to represent (it is not acceptable to have two aircraft painted with exactly the same scheme and serial) the aircraft does not have to be physically marked as the donor aircraft, this only needs recording in the documentation.

Replicas and Reproductions

2.25 A replica aircraft is a copy of an aircraft of historical significance that has been constructed to the original design. It may be possible for such a replica to be considered for the issue of a Permit to Fly, provided that it is not intended to be series manufactured. Approval for the construction of replicas will normally be limited to single examples which conform to the original design. There are exceptions to this, for example where the original manufacturer has re-opened a new production line based on the original drawings and jigs. Any design changes, which, for example, might be to improve the safety characteristics, or to allow substitution of obsolete materials, should be discussed and agreed with the CAA. Such changes should be sufficiently approved through modification approval either directly by the CAA or through an A8-21 organisation recognising the minor or major classification of the modification. Examples of these would be the new build Yak-3 and Yak-9 aircraft (albeit powered by Allison engines in place of the original Klimov units).

2.26 Replicas of ex-military aircraft may be accepted for the issue of a Permit to Fly using similar investigation processes to an original aircraft. Aspects to be considered when deciding whether a replica may be accepted include:

a. The likely number to be constructed;

b. The design standard adopted, including modification to the original standard; and

c. The production facilities and processes.

2.27 Other reproduction aircraft may be considered. These are a reasonable facsimile in appearance and construction of an aircraft made with similar materials and having substantially the same type of powerplant and operating systems. An example of this is the Yak-11 conversion to Yak-3/Yak-9 facsimile. In this case, as the original manufacturer and construction methods are not employed, the CAA will need greater assurance of the design and construction methods, usually through work with an A8-21 approved design organisation. For example, a material substantiation for the increased loads due to the change in capacity would be required – engine bearers, primary structure etc.

Flight Test and B Conditions

2.28 Each aircraft is required to have a flight test at the end of its restoration. In general this will be conducted by a suitably experienced pilot following discussion on the required Flight Test Schedule. It is however recognised that some specialist restoration and maintenance organisations have the same requisite capabilities as BCAR A8-9 organisations conducting flight trials under B Conditions. It is therefore considered that organisations that can demonstrate they have the necessary capabilities and arrangements in place that they could apply for an A8-9 B Conditions approval in order to allow themselves to self-authorise flight tests within the scope of their business.

2.29 Guidance on conducting Check Flights, eligibility of pilots and the relevant Schedules is contained with CAP 1038: http://publicapps.caa.co.uk/docs/33/CAP%201038%20JAN17.pdf

Chapter 3 Criteria for the Issue of a Permit to Fly

General

3.1 Before an aircraft can be issued with a Permit to Fly, its design must be shown to satisfy an acceptable 'basis for approval'. The criteria for approval that may be used are dependent upon the types of aircraft concerned and are listed in BCAR Section A, Chapter A3-7.

3.2 Part of the basis for approval of ex-military aircraft is service experience (BCAR Section A, Chapter A3-7, paragraph 3.4). However, although it can be difficult to determine the numbers of accidents that have occurred, their causes and the aircraft utilisation, all of which will be relevant to an assessment of airworthiness, the onus is on the applicant or BCAR A8-25 Organisation to establish this information. When assessing service experience, incidents can be ignored if it is clear that they were due to specific military operations that would not occur in civil use. The service experience acceptance criteria depend on a number of factors including the complexity criteria (see BCAR Section A, Chapter A8-25) and the mass of the aircraft.

3.3 Service experience can be useful in determining that an aircraft or component is safe, but it has to be used with caution and cannot be used where it conflicts with the need to meet specific requirements.

3.4 In the case of the first of a new aircraft type to come on the register, an in-depth test flight will be needed to show compliance with the flight requirements. As noted in Chapter 2 Paragraph 1.5, in general this will be conducted by a delegated suitably experienced pilot following a briefing on the required Flight Test Schedule, or by a contracted CAA Test Pilot.

Complexity Categories - Determination and Consequences

3.5 If the CAA has not previously accepted an example of the type the aircraft must be classified by complexity category (BCAR A8-25 Supplement 2 Paragraph 1.2). For single-engine piston aircraft (which are defined as simple in A8-25 Supplement 2 Paragraph 1.2), with a Maximum Take-Off Weight below 2730kg, an A8-25 is not required to substantiate this classification. If the aircraft falls outside of the above category and MTWA, then an A8-25 Supplement 2 signatory must make a case for the classification based upon the specified criteria and with reference to the below guidance.

3.6 Where the CAA has not been previously accepted an example of a type and it is not classified as 'Simple' by the definitions in BCAR A8-25 Supplement 2 Paragraph 1.2, then an investigation into the safety record of the type must be conducted and presented to the CAA for review. Further guidance on the establishment on this record can be found in A8-25 Supplement 2 Paragraph 6.1 and A3-7 Appendix 1 Paragraph 2.1.

3.7 In some cases, the classification of a type is easily assessed, but others may be less clear. The company signatory will be required to make presentations to the CAA in order to justify the assumed complexity classification. These presentations will include sufficient information on the design features of the type (including technical descriptions and Pilots Notes etc.) to justify the proposed classification. Specialised support and maintenance provision are examples of factors for consideration during classification.

3.8 In cases where the decision between Intermediate and Complex is marginal, it will be the subject of a CAA-administered Review Panel based on the information from paragraphs 3.6 and 3.7 above plus independent CAA research, including if necessary discussions with appropriate 3rd parties. In such cases, it is usual to cover the acceptability of the safety record concurrently.

3.9 Criteria for the classification by the CAA of ex-military aircraft as ‘simple’, ‘intermediate’ or ‘complex’ will be made according to the definitions shown in BCAR Section A, Chapter A8-25. However, to determine complexity category the following may be helpful:

a. To distinguish between *Simple* and *Intermediate*:

- *Simple* types are single piston engined fixed wing types only
- Multiple piston-engined fixed wing types are at least *Intermediate*
- All ex-military rotorcraft are at least *Intermediate*
- The inclusion of ejection seats would render an aircraft at least *Intermediate*

b. The distinction between *Intermediate* and *Complex* classifications is not so definite and some distinguishing features that help the CAA determine classification are:

- An aircraft may be classified *Complex* if the maintenance involvement is judged to be difficult or high, either because of packaging density within the airframe or because of the sheer extent of it. Examples include the Lightning, Harrier/Sea Harrier, Jaguar and the Vulcan respectively.
- The general philosophy is that if powered flying controls are fitted, manual reversion must be possible in order to be able to control the aircraft away from populated areas or crowds in the event of a power control failure. For example, this is why the AAN for the Sabre accepts only the A model of the F-86 aircraft as being eligible for the issue of a Permit to Fly in the *Intermediate* category, whereas the D model would be classified as Complex. However, a dual powered system may be regarded as an acceptable alternative.

- Auto-stabilisation systems (i.e. active control) that allow the aircraft to routinely fly within the normal flight envelope and which would normally have been used in military service (and thus would be needed in civil operation in order to render the safety record applicable) will bias the classification towards the *Complex* Category.
- Use of reheat within a turbine engine does not necessarily render the aircraft *Complex*, as the system may consist of little more than a High-Pressure pump and in cases of civil approval maximum weights achievable will be such that take-off performance would not be compromised significantly by failure of the system. For example, the MiG-17F has reheat and was accepted as *intermediate*. However, the required use of throttleable reheat or the requirement for reheat on the remaining engine in the event of an engine failure would render the aircraft in the *Complex* category.
- If the whole fuel system operates at high pressure (e.g. Lightning) this will bias the classification towards *Complex*.
- Reliance on integrated digital controls (such as Fly by Wire/Fly by Light), Electronic engine controls (FADEC), or reliance on EFIS/HUD will bias the classification towards *Complex*.
- Reliance on blown flying controls such as fitted to the Buccaneer will lead to the classification as being *Complex.*
- Reliance on reaction controls during any phase of flight will render the aircraft *Complex* (e.g. Harrier).
- Use of advanced materials (e.g. Carbon Fibre Reinforced Composite or metal matrix composites/aluminium lithium) in primary structure will bias the classification towards *Complex*.

3.10 In the event of an aircraft being classified as Complex, the formal involvement of the original manufacturer (or a suitable, CAA accepted, equivalent design organisation) is required to enable an appropriate level of continued airworthiness support to be available. This is to be written into the BCAR A8-25 exposition, countersigned by the OEM (or the ‘equivalent’ design support organisation), and will cover that organisation’s agreement of:

a. Safety record;
b. Design submission for initial approval;
c. Justification of any post-service modifications & repairs including component substitutions and of serviceability and applicability declarations for spares;
d. Continued airworthiness support details for the aircraft, not least relating to the particular aspects which rendered the aircraft *Complex*;
e. Confirmation of acceptability at each Permit renewal (at least annually).

3.11 Some types may only be considered supportable by the military service who operated them (where the service has taken on type airworthiness responsibilities) or by the original manufacturer. The Exposition of organisations approved to support *Complex* aircraft should include procedures detailing the necessary interface with the manufacturers providing support for the aircraft and of its critical equipment, and/or potentially an acceptable Military Authority. The nature and depth of such procedures will be subject to the agreement of the CAA. These procedures will also be required in the exposition referred to in subparagraph d) above.

3.12 In all cases where the type continues to be actively supported by the manufacturer (for example when the type is still in operational service), arrangement should be made where possible with the manufacturer to provide copies of all continued airworthiness information (i.e. Safety Bulletins, ST Instructions etc.) to the organisation and the CAA.

3.13 Note that proposing to de-activate some of the systems that may drive the classification towards ‘Complex’ such as auto-stabilization in order to make an argument for the type to be classified as intermediate may invalidate the safety record proposed to the CAA, as this is not likely to have been a configuration regularly used in military service except maybe in an emergency. Depending on the specific circumstances, this may not be acceptable to the CAA.

3.14 Proposing a normal operating regime in the civil environment that would have only been entered to in an emergency during military service will not be acceptable to the CAA.

Assessment of Safety Record (BCAR A3-7/B3-7 Appendix 1 Paragraph 2.1)

3.15 A formal assessment of the safety record is not necessary on types classified *Simple*, unless they are known to have a poor record, or they embody a highly unusual or hazardous feature such that the CAA considers this kind of justification is warranted. Additionally, for simple types detailed records may not be available to substantiate a quantifiable safety record. However, the reputations of such aircraft are generally known and these aircraft have been accepted on this basis, and subsequent examples accepted on the basis of precedent. If a new type were to be considered, the DLS knowledge of the type may be supplemented by a literature survey, consultation with recognised experts etc. in order to make a qualitative assessment as to the acceptability of the type on the basis of service experience.

3.16 Investigation of *Intermediate* and *Complex* aircraft of a specific type that the CAA has not previously accepted will commence with a demonstration that the aircraft type has a safety record in service acceptable to the CAA for its intended use. Combat losses or those directly attributable to specifically military operational causes may be discounted but appropriately qualified personnel should make a review employing such judgements. Aircraft loss rates are required, rather than fatal loss rates as such, since the occupants may have ejected. Data should be presented per million flying hours. Data should be such that the statistical nature of the basis of acceptance of the type remains valid i.e. the larger the fleet and the more flying hours, the better. Copies of the military records used to produce the statistics should be provided to the CAA for it to make its assessment of what may be discounted.

3.17 The organisations procedures should include presentation of the safety record (total loss and fatal accidents per million flying hours) to the CAA for assessment prior to commencement of the main investigation of design and build standard. The design signatory accepted by the CAA for the purpose will make such presentations.

3.18 It may be found that a particular aircraft was hazardous in specific operational circumstances, or that particular modifications rendered the aircraft hazardous. In this event, it may be that application of revised limitations may render the aircraft type acceptable to the CAA. For example, the Sea Vixen's record suffered by the inclusion of carrier borne operations, with their hazardous nature and lack of diversion availability, particularly when coupled with a fuel system that was difficult to handle manually. The aircraft safety record was rendered acceptable with such operations prohibited, and with the fuel system to be operated in automatic mode; complexity was agreed by the ARB as *Intermediate*.

3.19 More stringent targets may be set for *Complex* types. In the case of *Complex* aircraft, in most cases, the CAA will require that the OEM or 'equivalent' organisation supports such safety record submissions. The Design Liaison Surveyor will provide written confirmation of both complexity category and acceptability of the safety record (and of any appropriate provisos) to the applicant once these are agreed.

Chapter 4 Modifying or Repairing a Permit to Fly Ex-Military Aircraft

Who to apply to for approval of a modification or repair

4.1 Applications for the approval of modifications or repairs in respect of Permit to Fly aircraft shall be made to the CAA, except in the case of a minor modification approved directly by a BCAR A8-21 Design organisation with an appropriate scope. Ex-military aircraft overseen by CAA will require a submission for any major modification or repair to be made via such an appropriately approved Design Organisation.

Contents of an application for a modification

4.2 In general, all applications should contain the following:

a. Drawings, systems diagrams and schematics.

b. Justification, including structural evidence as appropriate.

c. A report showing compliance with the relevant paragraphs of an appropriate, agreed civil certification standard.

d. If necessary, a proposal for any ground and flight testing that may be required before the modification can be approved.

e. A revised mass and balance report for the modified aircraft (or if not yet modified, a prediction of the effect on mass and centre of gravity).

f. Maintenance manual/inspection schedule changes.

g. Flight Manual/Pilot's Notes changes.

h. Requirements for Continued Airworthiness information.

4.3 As laid out in BCAR A2-5, modifications are treated according to whether they are classified as 'major' or 'minor'. In some cases, modifications may be very minor, such as replacement of fittings with NATO standard, for compatibility with western aerodrome equipment and services, or replacement of metric instruments with UK standard. Precise definitions will vary between organisations. Classification of a modification is made in accordance with Appendix 2 to BCAR A8-21 and will be agreed by the CAA or by an A8-21 organisation. The following relative differences should be considered:

a. A Major Modification will have any of the following:

- An appreciable effect on weight, balance; structural strength; reliability; the flight manual; or on the manuals directly approved by the CAA or the Type

Certificate / Approval Data Sheet, including the Aircraft Flight Manual, the Operating Limitations, the Airworthiness Limitations in the Maintenance Manual, and the MMEL.

- Adjustment of the certification basis; introducing a new interpretation of type certification requirements; introducing aspects of compliance not previously accepted; the extent of new substantiation data and degree of reassessment and re-evaluation is considerable; where it alters the limitations directly approved by the CAA; where it introduces AD/MPD terminating action; where it introduces or affects a function the failure of which would be classified as hazardous or catastrophic.

This may involve a change to the aircraft which affects the design of the primary structure, flying controls, aerodynamic surfaces, (in most cases) engine(s), flight characteristics, limitations or its ground handling.

b. A Minor Modification is a change in the design or construction of an aircraft that does not meet the above classification. Appendix 2 to BCAR A8-21 should be referred to for guidance.

c. Wherever there is doubt with respect to the classification, the CAA should be consulted for clarification.

Where to find help in preparing a submission for a modification

4.4 For Major Modification applications to the CAA, the application should come from, or be supported directly by, a BCAR A8-21 approved Design Organisation with a scope of approval appropriate to the task in hand. A list of such organisations can be found on the CAA website.

4.5 To approve a design change that has an impact upon the aircraft's operation, a qualitative risk assessment will be necessary. Any amendments to original limitations and procedures specified in the Military Aircrew Manual will need to be established and implemented via a Supplement, which will be referred to in the AAN. For more substantial modifications, design substantiation will normally be submitted by an appropriate design approved organisation. An example would be justification of new replacement materials employed in a restoration of a *Simple* type. In this latter case, the basis of approval would be retention of equivalent strength. In other cases, an appropriate basis of approval must be identified and agreed with the CAA. Appropriate parts of BCAR Section K, JAR-23 and CS-23 have been employed for this in the past.

Standard Parts and Standard Modifications

4.6 Ex-military aircraft are dealt with as complete and individual entities. This means that the AAN for the initial Permit issue provides a consolidated clearance of the various modifications that have been embodied on that aircraft. This may not necessarily make it clear whether a 'series' modification, i.e. one which can be applied in a more generic sense to aircraft of the same or similar type, is approved for other aircraft. However, where identical modifications have been approved previously *for the same type and applicant* due account of this is taken when assessing the application of the modification to the subsequent aircraft. Additional expanded guidance will be included in Appendix 5 and may be found within CAP 1419.

Standard parts: Standard parts may be used under certain controlled circumstances.

4.7 Standard Parts – Critical nature

Bolts or fasteners used in areas of a critical nature which are replaced by bolts or fasteners of equal, or improved, specification with regard to dimensional tolerances and material properties should be authorised by modification procedure, (CAA Mod procedures apply), or be in accordance with the product support publications of the aircraft Type Certificate Holder or Type Design (See CAP 562, Leaflet 1-14).

In the event of an Airworthiness Approval Note (AAN) applying to a particular restoration project the Airworthiness Surveyor will ensure conformity with the AAN.

4.8 Standard Parts – Non-critical nature

It may be acceptable to replace original bolts or fasteners used in areas of a non-critical nature with items of equal, or improved, specification with regard to dimensional tolerances and material properties.

In the event of an Airworthiness Approval Note (AAN) applying to a particular restoration project the Airworthiness Surveyor will ensure conformity with the AAN.

4.9 Standard Modifications: As ex-military aircraft are not treated as series aircraft, modifications have to be justified for each individual aircraft. However, it is recognised that in some cases identical modifications have hitherto had to be submitted for subsequent aircraft of ostensibly same types. It is therefore considered that certain modifications, such as specific material substitutions or the use of standard additional systems on engines may be given a standard approval provided the initial modification is submitted by a suitably approved organisation and the item released under a suitable approval. It is recognised that it would be beneficial if, when a modification is the same as that previously approved in every respect, it could be used on subsequent aircraft without further approval. This saves unnecessary investigation on the part of the CAA and cost to the industry. However, the limiting factor is that the modification has to be the same in each respect. Any change invalidates the modification approval, however insignificant it may appear. Agreed examples:

a. Hurricane
   i. Fuselage, centre section etc. material replacement;

ii. Hydraulic pump fitment;
iii. Installation of 24v electrical system.

b. Spitfire
i. Nested spar materials;
ii. Engine pre-oil system

4.10 Note that CAA CAP1419 also extends some standard changes and repairs covered in CS-STAN to Annex I (Non-EASA) Aircraft. Further guidance can be found in Appendix 5 to this document and CAP1419.

4.11 Modification ownership: The applicant to the CAA normally owns the data approved under the modification. This clearly imposes restrictions on who can use this data as it clearly becomes propriety data. This ownership of data also leads to a potential overlap in modification requests and clearances. This may be an issue for the ex-military community to consider as it may be beneficial to have the ability to use certain modifications on vintage and ex-military aircraft on a series basis without re-investigation.

4.12 Use of a standard modification may be used subject to the ‘owner’s agreement’ provided the applicable modification information and components are made available.

4.13 Note that an AAN or Minor Modification approval only documents the approval of the modification. Modifications must be embodied utilizing the approved data such as manuals, instructions etc. These are usually held by the original applicant for the modification. The CAA cannot release this data to third parties without consent of the approval holder.

4.14 Material replacements: It is not CAA practice to insist on material release from CAA approved sources for aircraft operating on a Permit to Fly. Some material specifications employed in the 1940s and 1950s may be difficult to match with modern materials. If the original material is unobtainable, the applicant should contact a suitable DOA for an alternative specification, unless this has previously been approved. For components of a critical nature, premium selection procedures may apply. Premium selection is such as the testing of each length of tube or material used to ensure it meets the required properties.

Fabrication Element under the A8-23/24 Approval

4.15 For many organisations that held the A8-20 approval, and who were involved in ground up restorations, the capability for fabrication already existed. What has been required therefore is reinforcement of the importance of using the correct manufacturing/fabrication techniques and processes. With the introduction of BCAR A8-23 (specifically Paragraph 9.3) and A8-24 (specifically Paragraph 5.1), the ability for suitably approved organisations to manufacture or fabricate components and assemblies has been introduced. A capability list and procedures for this should be included in the company exposition for agreement and approval by the assigned GAU Airworthiness Surveyor. Guidance and Advisory Material will be developed in relation to this and included within this CAP when available.

4.16 Additional expanded guidance is included in Appendix 5.

Chapter 5 Maintenance Inspection and Revalidation of an Aircraft Issued with a Permit to Fly

Background

5.1 Air Navigation Order Article 40(3) states that a National Permit to Fly shall be issued by the CAA 'subject to such conditions relating to the airworthiness, operation or maintenance as it thinks fit'. Article 41 has provision for the Permit to Fly to cease to be in force if a Mandatory Permit Directive is not complied with or any inspection or maintenance required as a condition on the Permit to Fly is not completed.

5.2 Paragraph 8.2 of BCAR Chapter A3-7 refers to a Permit to Fly containing in certain cases 'any relevant maintenance requirements that are to be complied with'. Paragraph 9.2 refers to the issue of a Certificate of Validity and Appendix 4 in turn makes reference to all maintenance being carried out in accordance with the accepted maintenance programme.

General

5.3 Every aircraft requires periodic inspection and maintenance in order for it to remain in an airworthy condition. Whether used extensively or not, it will suffer from exposure to conditions that may initiate the onset of corrosion and general deterioration. This will be particularly true when it is routinely kept outdoors, or when used infrequently. Aircraft that are flown on a regular basis will accumulate normal wear and tear of moving components and this can extend to include static components through exposure to flight and ground loads and vibration. Extensive flying will obviously expose the aircraft to more extensive wear and in some cases may require additional inspections to be made. For example, an aircraft used for training or landing practice will require more detailed and regular inspection and in particular of the undercarriage and brake systems.

5.4 The basic premise upon which a Permit to Fly is issued and is kept valid is the satisfactory continuing airworthiness status of the aircraft. This can be achieved in a variety of ways but it is a fundamental principle of established airworthiness system to maintain the aircraft in accordance with a predetermined inspection regime supported by a number of maintenance interventions such as lubrication and/or component changes. Where a manufacturer supports the permit aircraft by virtue of it being an ex-military type or an ex-type certificated aircraft it is likely that the maintenance requirements may have been defined already. It is important therefore that some consideration be given to what maintenance is required in order that the aircraft's airworthiness can be assured.

5.5 The responsibility rests with the aircraft owner who must ensure that the aircraft is serviced and inspected periodically. Maintenance must be carried out methodically to a maintenance schedule agreed with the CAA to ensure that the inspections are timely and appropriate. For very basic aircraft, this may be a simple schedule of visual inspection points based on a manufacturers schedule and submitted to CAA. More complex aircraft may, however, require a detailed maintenance schedule that takes into account the specific recommendations of the aircraft or component manufacturer, including where appropriate, component overhaul requirements and the accomplishment of structural non-destructive inspection (NDI) techniques.

5.6 A record of the inspections and checks, as well as any defects found, must be kept so that a history of the aircraft can be built up. The entries of work carried out should be recorded in the aircraft engine and propeller logbooks, as required by Article 227 of the Air Navigation Order 2016 (ANO). The entries required are those listed in Schedule 7 of the ANO and must include details of inspections, repairs, replacements, modifications and overhauls carried out. It should be noted that whilst the logbooks may contain a summary of the work carried out, the extent to which this can be done may be dependent upon the existence of more detailed inspection worksheets. These will, in turn, form part of the aircraft logbook and must be retained.

5.7 If as part of the process of qualifying for the issue of a Permit to Fly a Permit to Test or Ferry is required, these are issued by the CAA.

5.8 If a Permit Flight Release Certificate (PFRC) is required in accordance with BCAR Section A, Chapter A3-7, the whole aircraft is to be certified for flight by an authorised person.

5.9 If any maintenance is carried out, except that carried out by the pilot, while a PFRC is in force, a ‘Permit Maintenance Release’ (PMR) will be required to certify the work carried out.

5.10 When a Permit to Fly (other than a Permit to Fly for test or ferry purposes) is issued:

a. The aircraft will also be issued with a ‘Certificate of Validity’ (C of V) which will then be re-issued annually.

b. A PFRC will not be required, if the C of V remains valid.

c. A PMR will be required following any maintenance other than that covered by paragraph 2.10.

d. If the C of V is allowed to expire, a 'Permit to Test', a PRFC and a PMR will be required.

5.11 Unless the aircraft is maintained under the auspices of an organisation approved under BCAR A8-23/24 (where the responsible persons are authorised under the terms of the organisation approval), the PFRC and PMR must be certified by a person authorised by the CAA in accordance with BCAR Section A Chapter A3-7.

5.12 For aircraft below 2730 kg MTWA operated on a Permit to Fly, pilot maintenance may be carried out in accordance with either the prescribed repairs and replacement privileges in the ANO, Section 3 Part 4; Regulation 12; or for those aircraft with a Permit to Fly validated by a person approved by the CAA for that purpose, pilot maintenance may be performed to the extent permitted by the procedures of that organisation. For pilot maintenance, the issue of a Permit Maintenance Release (PMR) is not required.

Maintenance of aircraft formerly issued with a Certificate of Airworthiness

5.13 An aircraft that would have normally qualified for a Certificate of Airworthiness may have been issued with a Permit to Fly if it was no longer being supported by a type certificate holder or manufacturer. These aircraft were manufactured under a type certificate and the design and maintenance documented. An example would be the Harvard/T-6 series where some are eligible for a CofA and some for a permit to Fly depending on the manufacturer.

5.14 The documentation provided by the manufacturer will, normally, consist of maintenance manuals, service manuals and other service information. A structural repair manual giving details of permitted repairs on the aircraft structure may also be available. An aircraft owner must not deviate from the procedures in these manuals, unless the change is supported by the manufacturer or another organisation and is approved by the CAA.

5.15 Owners of aircraft which have been manufactured according to a type certificate or an equivalent standard, will normally be required to use the appropriate replacement parts specified by the original manufacturer. Where the manufacturer is no longer supporting the aircraft type it may be possible to obtain alternative parts which can be used in lieu of the original specification; these will include items made under a Federal Aviation Administration (FAA) Parts Manufacturing Authorisation (PMA) for use on products of American origin. Unless specifically approved by the CAA, PMA parts may not be used on an aircraft originating in a State of Design other than the USA. Unapproved parts, those not approved either by the manufacturer or through a PMA approval, may not be used unless approved for installation on that specific aircraft according to a suitably approved minor or major modification.

5.16 Where the manufacturer lists details of overhaul periods or the limited life of certain critical components, these shall be complied with unless otherwise agreed by the CAA. Where the manufacture has not listed lives of such as engines or propellers, these may need to be agreed with the Design Surveyor in terms of Fatigue Index/Calendar time based on the usage and recorded in the AAN.

5.17 Airworthiness Directives, mandatory modifications and inspections, or airworthiness instructions of a mandatory nature, which are applicable to an aircraft type operating under a Certificate of Airworthiness, will apply to aircraft of the same type even if these are operated on a Permit to Fly (Reference CAP 661 MPD 1995-001 R5).

Maintenance of ex-military aircraft: Maintenance Schedules/Programmes

5.18 A maintenance schedule is an identified compilation of actions such as inspections etc. that provide a means of detecting the likely degradation of the aircraft structure, its systems and any defects that may occur in service. It is the primary means of determining the aircraft's continuing airworthiness status.

5.19 A generic schedule, such as the CAA LAMS document, provides a range of basic inspections and checks that could be customised to reflect the specific needs and systems installed in a particular aircraft. This is important as the installed equipment, and therefore the inspections needs, can vary between two examples of the same aircraft type. However, LAMS does not provide a suitable schedule for most ex-military aircraft, or any aircraft above 2730 kgs. It is important for ex-military aircraft that the original manufacturer's recommendations are followed as well as any military requirements that may have supplemented them. This ensures that the military in service experience of the type is reflected in the maintenance and inspection required to sustain airworthiness.

5.20 This position is often written in as an element of the associated AAN. It should be noted that the AAN, as it defines the status of the aircraft with regard to Permit issue belongs to the aircraft and not the applicant or maintenance organisation. The maintenance provision is however not always visible, and it is recognised that it would be better to have some basic requirements for a maintenance schedule rather than something derived from the wording in an AAN. This will therefore be included in the Permit to Fly Conditions.

5.21 The continuing airworthiness requirements are normally specified and outlined in the AAN. This often relates only to the original military servicing schedules, which were based upon manufacturer's programmes and much higher levels of annual utilisation. In some cases, the AAN refers to use of the CAA LAMS schedule, despite the weight and complexity of the aircraft, e.g. Spitfire, not aligning with that simplistic approach. It is therefore essential that schedules or programmes are developed that reflect the most appropriate information for the specific operation.

5.22 An ex-military aircraft will have been maintained in accordance with well-defined maintenance programmes and schedules which took into account the operational environment and the way the aircraft were used. They may have included specialised checks such as non-destructive testing and also have maintenance actions on operational equipment. It is important that all of these requirements, where appropriate, are complied with during the maintenance.

5.23 The maintenance data will be agreed by the CAA and this will be referenced in the AAN associated with the issue of the Permit to Fly. In the case of ex-military aircraft this will normally refer to the military publications for the aircraft type. The maintenance schedule for the aircraft will need to be reviewed and amended to take account the utilisation and type of operation. The flying hour related tasks may need to be converted to appropriate calendar periods.

5.24 Some aircraft are fitted with fatigue meters to record details of the usage spectrum during each flight. This data is used in conjunction with defined procedures to calculate the used life of the aircraft which take into account the method of operating. An example of this is aerobatic flying which may accumulate fatigue at three or four times the rate of normal flying. This method of working ensures that due attention is paid to maintenance activities according to the use of the aircraft. Where fatigue meters are not fitted or are unserviceable, the CAA may still require usage factors to be considered and taken into account, dependent upon the original design criteria and this will be recorded in the AAN.

5.25 Ex-military aircraft may have specific life limits for the aircraft structure or critical components defined by the manufacturer, these limits must not be exceeded. Where the manufacturer permits further operation for a period dependent upon the embodiment of additional modifications by more comprehensive and in-depth maintenance checks, these must be carried out before an extension to the operating life will be agreed. There will be no extension of aircraft life limits beyond those that are defined and supported by the manufacturer.

5.26 Ex-military aircraft may have safety equipment necessary for the type and nature of military operations, primarily ejector seats. BCAR Section A, Chapter A8-25 requires special provision for the maintenance of this equipment to be included in the maintenance programmes. It is also required that appropriate organisations are available to provide for the overhaul of these items. Ex-military aeroplanes above 2,730 kg MTWA and ex-military rotorcraft of any weight are required to be maintained by organisations approved to BCAR A8-23/24. This imposes restrictions on the level of maintenance that may be performed by the owner.

5.27 Spares for ex-military aircraft should, whenever possible, be obtained from original sources or through known and reputable distributors as verified by an organisation's Quality Audit system. It is important that the owners of ex-military aircraft ensure that spares conform to the original design standard, are compatible with the modification standard of the aircraft, are serviceable and within specified operational and storage limitations. Additional information relating to procurement of spares can be found in BCAR A8-23/24.

5.28 Where the aircraft is one which is of an historic/vintage nature, original spares may not be available. Agreement from the CAA must be obtained to manufacture spares to original drawings through an approved supplier such as (but not exclusively limited to) a BCAR A8-21 manufacturing organisation. An organisation that is approved under BCAR A8-23/24 may also be able to manufacture certain items locally as agreed by the CAA. Where the aircraft is being extensively restored or substitutions are being made for materials that are no longer available, the agreement of the CAA must be obtained.

5.29 Where the aircraft is ex-military and not required to be maintained in accordance with BCAR Section A, Chapter A8-23/24, the CAA will oversee the project directly to agree the maintenance that is required and to authorise the nominated engineering staff. Alternatively, the aircraft may be transferred to LAA oversight if within the scope of their terms of approval. In either case, the owner remains responsible for ensuring that the required maintenance is carried out.

Low Utilisation and Calendar Lives

5.30 It is clear from the manner in which permit aircraft are operated that in many cases the actual utilisation of the aircraft is very low – often less than fifty hours per year. In addition, the history of these aircraft can include extended periods parked or in storage. This does not reflect the expected utilisation upon which a manufacturer may have developed an outline schedule of inspections. In practice, there is a danger therefore, that critical inspections may be not be accomplished for a number of years simply because they are hours-based and the utilisation is less than that expected.

5.31 For maintenance schedules to be effective there clearly needs to be a balance between the required inspections and its likely effectiveness taking into account the time between inspection events. If the utilisation does not reach the expected annual figure upon which the schedule is based, then an alternative inspection strategy needs to be considered and adopted.

5.32 In some instances, this requires hourly-based inspection items to be reviewed and a calendar backstop implemented. However, the aim should not be to end up with a prescriptive and restrictive schedule but one which provides that balance between the low utilisation and the likely onset of deterioration.

5.33 Some manufacturers made provision for low utilisation schedules when, for example, a product was in military service. That low utilisation was never anticipated at the levels being seen on many permit aircraft. Care must therefore be taken in interpreting data, which at first glance appears to suit operational circumstances. Consideration therefore needs to be given for the provision of additional guidance on the effects of extreme instances of low utilisation on manufacturer’s data and their impact on modern maintenance schedules.

5.34 There are many instances where lives have been set for components, such as seals etc. where the continuation of an hourly-based inspection/replacement regime does not account for a potential degradation of the seal material due to system inactivity or the resulting calendar period. The same applies to the overhaul lives for ancillaries such as fuel and air system components. There have been several accidents where such degradation or failure of fuel system components has been a causal factor. There is therefore a need for the identification of overhaul lives for seals, fuel components and other ancillaries as well as the process for approving replacement degraded seals, fuel components and other ancillaries.

5.35 In many cases, additional inspections may provide an element of compensation for this. However, the need to replace seals or internal components within such as fuel and other control systems needs to be carefully considered, irrespective of the apparent satisfactory operation of the system at a point in time. For example, air system leaks such as on bleed valve scheduling controls are also a concern and have been identified by AAIB as possible contributors to past events. A philosophy of adopting a condition monitoring approach on older aircraft is not necessarily acceptable. The aircraft and its systems were not designed with such a philosophy in mind. Some trending of basic performance parameters may however contribute to ensuring continued airworthiness.

5.36 The need to consider component lives is also very much true for engines and rotable/finite life components. In many cases, these critical components are no longer subject to support from the manufacturers. The normal continuing airworthiness information that would be promulgated with such support is therefore missing, particularly with regard to the effects or implications of ageing aircraft and systems. In addition, there is little information available from service regarding the current condition of these components. In addition to the manufacturers recommended overhaul periods, calendar lives may need to be applied for preventative maintenance. These limits will be specified in the AAN raised for the aircraft.

5.37 Whilst the CAA has published some data with regard to engine overhaul lives, e.g. CAP 747's Generic Requirement (GR) No. 24, this document applies only to piston engine designs up to 400hp and does not cover all the designs which are fitted to ex-military aircraft. There is ongoing concern over the potential effects of corrosion on both critical and non-critical engine components within engines found on ex-military jets operating on permits. The failure of a non-critical part (e.g. single blade, gear drive shaft) will usually result in the loss of the aircraft. Even on twin engine aircraft, the loss of performance if one engine fails following a non-critical part failure can result in loss of aircraft in certain phases of flight). Likewise, the full effects of ageing on the early design of some light aircraft engines, e.g. the Gipsy Major, are not well known, particularly if the issue of availability of spares is accounted for.

5.38 The CAA has issued CAP 562 "Civil Aircraft Airworthiness Information and Procedures", Leaflet 70-80, "Guidance Material for Ageing Engine Continuing

Airworthiness", and a further two MPDs relating to ageing engine issues, 2016-001 and 2016-002.

5.39 Further Guidance will be issued in Appendix 6 to this CAP

5.40 There is a shortage of information on ageing aircraft systems and wiring, particularly in ex-military aircraft. This too gives rise to a cause for concern. It is recognised that where extensive restoration has taken place the original components will have been refurbished and perhaps wiring replaced. However, there are many instances for this to remain an issue where little has been done to the aircraft and its original build standard. This was highlighted in the Haddon-Cave report following the Nimrod Review that drew particular attention to the degradation over time of such components including seals. Whilst guidance will therefore continue to be established for ageing aircraft systems, the CAA has welcomed the opportunity to present an independent review of the condition of wire and wiring materials found in British ex-military aircraft, as guidance. It should be noted that the wiring report was not created as a scientific examination of ageing wire and cabling systems, but rather as comment on the possible problems which may be encountered when assessing such material for serviceability, from a practical engineering standpoint, as previously experienced by its author. The CAA considers this guidance worthy of consideration with respect to the continuing airworthiness of ageing ex-military aircraft.

5.41 Further Guidance including the wiring report can be found in Appendices 6 and 7 to this CAP

Approval of Maintenance Schedules

5.42 Depending on the size and/or power of the aircraft, a maintenance schedule for a Permit to Fly aircraft does not always have to be approved by the CAA but it does need to be suitable for the intended purpose. Most maintenance schedules for permit aircraft are accepted. It is therefore incumbent on the aircraft owner/operator to ensure that the requirements are met, in conjunction with the certifying engineer. However, it is also incumbent on the CAA to ensure a consistent approach in how maintenance schedules are accepted or approved, both at initial issue and for subsequent amendments.

5.43 As experience has been gained on generating bespoke maintenance schedules, the information in the AAN (which is generally a 'snapshot' at its entry to civil service) may have become out-dated. There is therefore an ongoing requirement to confirm the current applicable regime rather than assume the AAN reference remains correct.

5.44 The general requirements for the approval of maintenance schedules and programmes are in BCAR Section A Chapter A6-1 Supplement 4. Whilst these are applicable to aircraft operating on a Certificate of Airworthiness, the general principles behind the maintenance schedule development still apply.

5.45 BCAR Section A, Chapter A3-7 specifies that an applicant for a Permit to Fly must demonstrate how the aircraft has been maintained and overhauled, including those elements relating to lifed components. It also states that applicants must demonstrate how they will provide the competence and the resources necessary to maintain the aircraft in the future. In this respect, a maintenance schedule will go some way to satisfying these requirements.

5.46 BCAR Section A, Chapter A8-25 also contains information on what is expected of the organisations in respect of the development of maintenance schedules for ex-military aircraft, and include information on typical features of these aircraft, such as ejector seats, their pyrotechnics and the procedures to be followed.

5.47 The Light Aircraft Association (LAA) will provide additional guidance to their members regarding acceptable programmes for aircraft under their control.

Service information provided by manufacturers

5.48 A manufacturer can take account of the in-service experience of all of its fleet, providing that any significant evidence of defects or deterioration has been reported to them. The continuing airworthiness information published by them, whether it is a maintenance manual, service bulletins or other service information can make the difference in ensuring the aircraft is maintained properly.

5.49 An aircraft in service may suffer a failure of a component, or of a system, which gives rise to concern about the continuing airworthiness of the aircraft type. In the case of a type certificated aircraft the manufacturer may issue service information. This may take the form of a service bulletin, or service letters, etc. that define the inspections, modifications or other work which is considered necessary to determine if the failure condition is present or to correct an unsafe condition. These inspections may be classified as 'mandatory'.

5.50 For aircraft that were type certificated but are now operating on a Permit to Fly, the National Aviation Authority (NAA) of the State of Design should issue an 'Airworthiness Directive' or equivalent notice to address potential hazards. For such aircraft the CAA will normally require compliance with these Airworthiness Directives, as notified in CAP 661 'Mandatory Permit Directives'.

Mandatory Permit Directives and Airworthiness Directives

5.51 The other key issue to bear in mind is the mandatory information promulgated by the State of Design or the State of Registry. This could be Airworthiness Directives or Mandatory Permit Directives and will be complied with. Whilst it is accepted that a Permit to Fly aircraft does not need to meet ICAO international standards, it is erroneous to believe that because a type certificated engine is installed in a Permit aircraft the AD can be ignored. ADs and MPDs are expected to be included in any maintenance schedule for the aircraft type.

5.52 MPD1995-001 R5 Applicability of ADs to UK PtF aircraft (of a type that previously operated on a UK CofA) addresses this.

5.53 It is necessary for the owner to ensure that mandatory inspections and Airworthiness Directives for the aircraft, engines and its components are carried out. Where the CAA identifies an unsafe condition, on an aircraft type with a Permit to Fly, a ‘Mandatory Permit Directive’ will be issued requiring inspection of the aircraft for that particular defect and its rectification. The LAA also issue safety bulletins as part of their continued airworthiness support for those types operating within their organisation. This may also result in a CAA MPD.

5.54 Where the aircraft is supported by a manufacturer but is not designed and built to a type certificated standard, e.g. an ex-military aircraft, the manufacturer may identify a hazardous condition and issue appropriate service literature. However, the NAA of the State of Design will not normally issue an airworthiness directive since the aircraft is not type certificated. In such a case the UK CAA will consider the content and implications of the service literature that has been issued and, if appropriate, will issue a Mandatory Permit Directive (MPD) for the aircraft based upon that information. The MPD will state the work that is required and the timescales in which it must be accomplished.

5.55 Where the aircraft is not supported by a designated manufacturer or type certificate holder the CAA may still decide to issue an MPD to address an unsafe condition. This will, in the absence of specific inspection criteria issued by the manufacturer, normally result from a defect report or an occurrence report sent to the CAA. The CAA will decide the nature of the inspection required and issue an MPD to detail the work required.

5.56 Certain equipment, such as the engine or propeller may be to a type certified design, in which case, the requirements of any airworthiness directive in respect of that equipment should be complied with.

Maintenance and installation of radio equipment

5.57 Attention is drawn to the installation and maintenance of radio equipment. In accordance with ANO Article 77:

a) It must be of a type approved for use by the CAA;

b) It must be installed in an approved manner;

c) It must be maintained in a serviceable condition, with appropriately authorised radio engineers certifying for any such work.

5.58 Approval of the radio installation in an aircraft with a Permit to Fly forms part of the aircraft radio licence issued by CAA Directorate of Airspace Policy. Changes to radio equipment are mods and require approval by the CAA or an approved organisation. This can be part of the initial approval or may be a standalone modification. It is acceptable to CAA for the removal of redundant radio/avionic equipment providing the system is made safe by such as capping and stowing of cables, removing fuses and the prevention of re-instatement etc. This should be covered by a modification submission as it may affect such as the Weight and Balance Schedule. This may in certain circumstances be a standard modification. See Appendix 5 for guidance on this.

Chapter 6 Operation of a Permit to Fly Aircraft

General

6.1 Permits to Fly contain certain conditions that govern the manner and extent to which the aircraft may be operated. These include the limitations on the operation of the aircraft, such as speeds, engine performance etc. Other issues that may be addressed are take-off and landing performance, the number of occupants and limitations on areas that can be over flown and under what flight conditions. There may also be specific limitations associated with the design standard, for example a 10,000 ft. operating height restriction when there is no oxygen system fitted.

6.2 All ex-military aircraft of greater than 2,730 kg MTWA are required, as a condition of the Permit to Fly, to operate in accordance with CAP 632 – Operation of 'Permit-to-Fly' Ex-Military Aircraft on the UK Register. CAP 632 requires that operators define various operational parameters and constraints in an Organisational Control Manual (OCM). The OCM is subject to agreement by the CAA before operations can commence. The CAA will audit operations at regular intervals, normally annually, to ensure compliance with both the operational constraints of the Permit to Fly and the method of operations as detailed in the OCM.

6.3 Aircraft operating under a Permit to Fly are generally not allowed to carry out commercial air transport flights.

6.4 The operation of an aircraft is normally restricted to recreational or private flying, but commercial work may be permitted in the following circumstances:

a. Flying displays, associated practice, test and positioning flights or the exhibition or demonstration of the aircraft, when only the minimum crew should be carried – Article 11 of the ANO 2016 refers. Pilots must consult CAP 403 – Flying Displays and Special Events: A Guide to Safety and Administration Arrangements.

b. Flying training in ex-military aircraft with a Maximum Take-off Mass Authorised (MTMA) exceeding 2,730 kg. In order to facilitate proper pilot conversion training in ex-military aircraft, depending upon the particular circumstances, the CAA may grant an exemption to the provisions of the ANO 2016, in order to permit full remuneration for pilot conversion training (aerial work) to be undertaken in ex-military aircraft when these are operated under the terms of CAP 632.

6.5 Certain other activities which would previously have been classed as aerial work may be carried out by Permit to Fly aircraft subject to specific limitations as follows:

a. Flights classed as non-commercial under Article 141 of the ANO, undertaken for the purpose of giving instruction, when the only payment made is for the services of an instructor;

b. Operation under the Safety Standards Acknowledgement and Consent framework.

Operational limitations

6.6 The operational limitations applicable to aircraft with a Permit to Fly are contained in the following documents:

a. Article 42 of the ANO 2016; for those limitations of a general nature that are applicable to all classes of aircraft operating on a Permit to Fly. The principal limitation is that Permit to Fly aircraft are restricted to flight by day and in accordance with Visual Flight Rules (VFR) unless the prior permission of the CAA has been obtained. Permission for flights under Instrument Flight Rules (IFR) will only be given in exceptional circumstances, such as, to meet a long-distance ferry requirement. In such a situation, the alleviation would be subject to agreement on aircraft instrumentation and pilot qualifications. Assessment and approval of any design aspects necessary for flight under IFR will also be required.

b. The individual aircraft's Permit to Fly; for those limitations that are applicable to either that individual aircraft or that class of aircraft. In particular, restrictions on flight over congested areas will be contained in the individual Permit to Fly as well as other specific conditions such as altitude limitations.

c. CAP 632 - Operation of Permit to Fly Ex-Military Aircraft on the UK Register, which deals with the operational control of ex-military aircraft with an MTMA in excess of 2,730 kg.

Alleviations from the commercial air transport or aerial work requirements applicable to aircraft operating on a Permit to Fly

6.7 To reflect the lower level of airworthiness assurance afforded by a Permit to Fly compared to a Certificate of Airworthiness there are a number of restrictions and prohibitions on the use of an aircraft with a Permit to Fly as detailed in the Air Navigation Order 2016. Examples of these are shown below:

6.8 Hiring of aircraft. The following applies:

a. An aircraft issued with a Permit to Fly may not be hired – Article 42 refers.

b. An aircraft issued with a Permit to Fly may not undertake commercial operations except in particular circumstances – Article 42 refers.

c. An aircraft issued with a Permit to Fly may fly for the purpose of the giving of flying instruction provided this is done under the auspices of a flying club and in accordance with the conditions listed on the individual Permit to Fly – Article 42 refers.

6.9 Charity flights are not permitted with passengers if the aircraft is operating on a Permit to Fly - Article 12 of the ANO and CAP 1330 refer.

http://publicapps.caa.co.uk/docs/33/CAP%201330%20Charity%20Fight%20InFocus%202EdFINAL.pdf

6.10 Cost sharing is permitted for aircraft operating on a Permit to Fly subject to compliance with the requirements in Article 13 of the ANO.

International flights by aircraft operating on a Permit to Fly

6.11 The Permit to Fly is not compliant with ICAO Annex 8 (Airworthiness of Aircraft) and which means it is not an internationally recognised document and aircraft operating on them are not certified to an internationally recognised standard. The Permit to Fly is, therefore, only valid within the UK airspace unless:

a. an exemption has been granted by the CAA permitting a flight or flights abroad (this exemption is normally given as standard wording on the Permit to Fly), and

b. permission in writing has been obtained from the national aviation authority of each country that is to be overflown, or in which a landing is to be made, for the flight or series of flights.

Safety Standards Acknowledgement and Consent

6.12 As referred to in paragraph 6.5 above, CAA has developed a framework by which passengers may buy rides in single piston engined ex-military aircraft that have a Permit to Fly. This is described in detail in CAP 1395:

6.13 CAP 1395 Chapter 6 identifies the basic airworthiness considerations for SSAC. In full, the airworthiness considerations for SSAC are:

a. For aircraft that operate on a Certificate of Airworthiness (CofA), the airworthiness standards and limitations associated with the C of A must be maintained. No further airworthiness considerations are required, but CAP 1395 must be followed in respect of limitations to the applicability of SSAC to these aircraft.

b. For all Permit to Fly (PtF) aircraft, points relating to increased utilisation and the potential increased risk associated with this must be addressed in accordance with the requirements of CAP 1395 paragraph 6.6, in relation to i) The anticipated utilisation of the aircraft in the SSAC role as compared with current utilisation, ii) Resulting changes to the maintenance programme, iii) Modifications fitted on a trial basis, iv) A review of all applicable airworthiness directives and/or MPDs and AMOCs to them; v) Revisions to aircraft placarding.

c. For Permit to Fly aircraft that fall into the intermediate complexity classification category, the CAA must be additionally satisfied that standards relative to both design and maintenance of these more complicated aircraft are such that they can demonstrate a level of safety that is in line with an equivalent type certificated aircraft. To achieve this, the SSAC applicant will submit a report for airworthiness assessment outlining the appropriateness of the aircraft design standard and individual aircraft condition which may go beyond the airworthiness acceptance for the basic Permit to Fly, including

   i. The acceptance of a suitable maintenance programme reflecting the proposed SSAC-specific utilisation.

   ii. The identification of means to track and monitor component lives

   iii. The identification and control of critical parts

   iv. Compliance with any relevant civil Airworthiness Directives (where the type has (or is of) a civil derivative.

   v. Where possible, original equipment manufacturers' support for the initial assessment and continued airworthiness commitment.

   vi. Where the occupancy of the aircraft is to be increased beyond the basic limits, either concurrently with an SSAC application or independently, the points within Appendix 3 (A-3.5.8) of this document must be addressed.

   vii. Provisioning of placards to identify the means to operate emergency exits, cladding of vertical posts if protective helmets are not worn, use of flying suits to minimise risk of inadvertent seat belt release and the placing of one crew member in the cabin where passengers are seated.

   viii. Aircraft fitted with ejection seat systems whether or not active, will be subject to an airworthiness review to verify the status of the system and ensure appropriate occupancy protection and egress is provided for.

   ix. In addition to the above airworthiness considerations, the operator's history should be identified for review, to include accidents and incidents, regulatory compliance and Authority surveillance history. Where changes for SSAC operation are needed due to limitations

   x. imposed at Permit to Fly issue, these would be subject to revision and the SSAC application would need to be supported by a separate Major Modification application in accordance with the (CAP 553) BCAR A2-5.

d. For Permit to Fly aircraft that fall into the complex complexity classification category, a policy to accept applications for SSAC has not been established.

e. An example of the aircraft provisions necessary to satisfy c) for SSAC, can be found within Addendum 2 of AAN29115 for G-UHIH.

Chapter 7 Publications

Mandatory Requirements for Airworthiness (Mandatory Permit Directives, Generic Requirements) etc.

CAP 747 – Mandatory Requirements for Airworthiness

Obtaining Permits to Fly

CAP 553 – BCAR Section A - (Chapter A3-7).

Modification of an aircraft

CAP 553 – BCAR Section A.

CAP 562 – Civil Aircraft Airworthiness Information and Procedures (CAAIP).

CAP 1419 – Guidance for applicants on preparing applications for the approval of minor modifications to non-EASA aircraft (Includes) Standard Changes/Repairs)

LAA Technical Leaflet 3.01 – Modification of LAA aircraft

Certification

CAP 553 - BCAR Section A.

CAP 554 - BCAR Section B.

CAP 462 – BCAR Section C (Engines and Propellers) (Available upon request)

CAP 463 – BCAR Section D (Aeroplanes) (Available upon request)

CAP 467 – BCAR Section K (Light Aeroplanes) (Available upon request)

EASA CS-23 – Normal, Utility, Aerobatic and Commuter Aeroplanes

Maintenance and repair practices and schedules

CAP 553 – BCAR Section A (Chapter A8-23, 24 and 25).

CAP 554 – BCAR Section B.

CAP 562 – Civil Aircraft Airworthiness Information and Procedures (CAAIP).

CAP 661 - Mandatory Permit Directives Issued prior to 1st January 2001.

Mandatory Permit Directives issued since 1st January 2001. Airworthiness Directives of the NAA (for non-UK aircraft) should be found at other NAA websites

List of CAA Safety Notices - UK Air Law

CAP 393 - Air Navigation: The Order and the Regulations (ANO).

Flying Abroad

ICAO Annex 8.

LAA Technical Leaflet 2.08 – Permit Aircraft Flying Abroad.

Note that flying abroad on a PtF may require an overflight permission from the relevant state(s) National Aviation Authorities.

Operations

CAP 632 – Operation of Permit to Fly Ex-Military Aircraft on the UK Register.

CAP 403 – Flying Displays and Special Events: A Guide to Safety and Administration Arrangements.

CAA Website: www.caa.co.uk

APPENDIX 1: The Airworthiness Approval Note (AAN)

A-1.1 The CAA General Aviation Unit Airworthiness Design and Certification Surveyor compiles the Airworthiness Approval Note based on either the applicant's or the A8-25 Supplement 2 organisation's design report. Much reliance is placed on the design report; however, CAA will review this carefully and carry out its own research as necessary for omissions as well as additional information. Reliance is placed on the approved A8-25 organisation to hold adequate records to justify the approval of each individual aircraft, so that CAA records need not be so comprehensive. The AAN is a 'snapshot' of the accepted design and modification standard of the aircraft at the point it is presented for its initial Permit to fly (i.e. its entry to civil service). It should be noted that changes may take place over time that may not result in CAA updating the AAN, but any such changes whether they are modifications, repairs or documentary changes such as a new maintenance programme, must be appropriately approved and recorded in the aircraft's records).

A-1.2 The AAN will follow a set format that is applicable to all National approvals (albeit that not all are applicable to ex-military aircraft) and the headings and their contents are described below. This intended to allow both the applicant and the CAA to fully understand the reasons behind the information required and how this is important in the approval process.

Introduction

A-1.3 The AAN will state the purpose for which the AAN is being issued.

A-1.3.1 The AAN will summarise the history of the aircraft as part of the introduction. This is a means of attesting to the veracity of the identity as well as showing why some aspects of investigation may have been necessary and for genuine ex-military aircraft the level of restoration and maintenance work carried out for Permit to Fly issue

A-1.3.2 The history of the aircraft may influence aspects of investigation. For example, if an aircraft has been employed as an experimental "test bed" it will be necessary to review how it has been returned to an acceptable "service standard" i.e. with experimental modifications removed.

A-1.3.3 Restorations: Some restorations may involve a fundamental rebuild with most of the structure being replaced. As long as the GAU Design and Certification Surveyor is satisfied that the aircraft involved is a genuine specimen, so that in essence the provenance or identity is established and retained, the project is accepted as a restoration rather than as a replica. This distinction may be extremely important in the eyes of the owner/collector.

NOTE: Applicants records should include all available supporting data for the history – for example copies of the log book, manufacturing records, military records etc.

NOTE: The AAN is a record of the investigation carried out by the CAA. For some simple types, the content of the AAN may sufficiently replace a specific design report. In other cases a formal report should be submitted from which the AAN can be created (certainly for types classified as intermediate and above and for restorations regardless of classification).

Aircraft Build Standard/Modification Definition

A-1.4 The AAN will describe the aircraft. It will make reference as necessary to a Type Certificate Data Sheet and if available, such as the build definition, drawings, mod leaflet, installation instructions etc.

A-1.5 Description: The description section of the AAN is usually kept brief, referring to manuals for detail. It is recommended that the design organisation include much more detail in their report for the information of the Surveyor, as this will reduce the number of questions during the approval process. Items considered include:

a. Whether the aircraft was previously type-certificated and there is a TCDS;

b. The configuration and construction method of the aircraft, such as whether the aircraft is a biplane or monoplane of wood or metal construction.

c. Control actuation – rod, cable, chain operated etc.

d. Pneumatic and hydraulic systems.

e. Fuel system and tankage;

f. Electrical system.

g. Powerplant: For each engine fitted, the report will identify last release to service, source of limitations/ratings, time between overhauls and time attained (whether in cycles or hours, units should be compatible for comparison). For turbine engines, the time both attained and remaining on critical Group A (Life Limited) parts should also be recorded. Where applicable, engine calendar time remaining will also be identified. Permanent company records will include a copy of each engine release to service and the last logbook page showing hours/cycles attained. Some engines may require special provisions or additional limitations (for example, Goblin engines employed early “stainless” steels which require particularly careful inspection for pitting corrosion) and may be subject to flight time/cycle penalties to cover ground running in lieu of maintenance. Calendar lives between overhaul may therefore be required. Consultation with CAA may be necessary.

h. Propellers (if applicable): If the aircraft is propeller driven, propeller type must be specified (Make, type, material, number of blades, blade/hub numbers, pitch and diameter) and justified. Usually this justification is by reference to documentation showing that it is the type originally fitted on that engine/airframe combination. However, if the engine has changed or if any modifications are involved, this aspect may require significant investigation. Compliance with CAP 747 Generic Requirement 17 may be required.

i. Transmission Systems (If Applicable): This section is intended to cover such items as gearboxes, drive shafts, standalone rotor brakes, free-wheel units, expansion couplings, oil coolers, cooling fans etc. This section will be applicable in the main to rotorcraft, but also to aeroplanes such as the Gannet that have contra-rotating propellers. For each transmission system component fitted, the report will identify last release to service, time between overhauls and time attained (whether in cycles or hours, units should be compatible for comparison). Permanent records will need to include a copy of each transmission system component release to service and the last logbook page showing hours/cycles attained.

j. Rotor Heads and Blades (If Applicable - Rotorcraft): For each rotor head fitted, the report will identify last release to service, time between overhauls and time attained (whether in cycles or hours, units should be compatible for comparison). Permanent company records will include a copy of each rotor head release to service and the last logbook page showing hours/cycles attained. For each rotor blade fitted, the report will identify last release to service, time between overhauls and time attained (whether in cycles or hours, units should be compatible for comparison). Permanent company records will include a copy of rotor blade release to service and the last logbook page showing hours/cycles attained. Some rotor blades may require special provisions. For example, early helicopters had rotor blades made of wood and were fabric covered. Special maintenance actions may be required in this case. For each drive train accessory fitted, the report will identify last release to service, time between overhauls and time attained (whether in cycles or hours, units should be compatible for comparison). Permanent company records will include a copy of the drive train accessory release to service and the last logbook page showing hours/cycles attained.

k. Radio/Avionics: Only CAA approved radio/navigation equipment may be operational, although sometimes, old equipment remains fitted for reasons of authenticity (e.g. as have previously been accepted on some Spitfires). In some cases, there is an equivalent civil set and approval is straightforward. In other cases, the applicant must seek an appropriate declaration from the equipment manufacturer. See Chapter 5 Paragraph 5.58.

Assessment of Conformity to Type Standard

a. In principle, the aircraft is accepted on the basis of an appropriate degree of conformity to a type with an acceptable safety record. Any departures from this standard must be justified more carefully, however, and it must be remembered that A8-25 Supplement 2 approval does not include the privilege to carry out design of modifications, only to make recommendations to CAA. Depending on the modification(s) proposed appropriate design organisation(s) might therefore be required to propose substantiations. Demonstrating conformity or otherwise is achieved via the aircraft standard/design status report providing evidence as to the original build standard and including a checklist against each manufacturers modification required for airworthiness. For a UK-designed aircraft this means each modification classified b/2 or above in the AP Master Modifications List.

b. While a comprehensive list is available for more modern machines (Vampires onwards), earlier machines suffer from lack of documentation and so the most comprehensive list should be compiled. For example, the best available AP Master Modifications List for many Spitfire types commences at number 736. For some types it may not be possible to obtain such documentation. In such cases the CAA will assess what might be acceptable.

c. The design report will refer to subsidiary documentation including modification checklists, fatigue audit, etc. to show that the particular aircraft matches the design standard for which the safety record was generated. Simple types may not be submitted through an A8-25 Supplement 2 approved organisation, but such checks will still be made. These checklists will form part of the permanent company records covering justification of the aircraft.

d. The A8-25 Supplement 2 organisation will also compile checklists against other service instructions including for example RAF Special Technical Instructions (STIs), Service Instructions (SIs) etc. For US aircraft, service requirements such as Technical orders may be listed in an FAA TCDS for the aircraft. Note that although there might not be a TCDS for the specific variant, Technical Orders for other variants of the same type might be applicable, such as is the case where ones applicable to the P-40B are included in the TCDS for the P-40N. These will be captured in the AAN.

e. Compliance with Mandatory Permit Directives promulgated by CAA for the type is also required.

f. Deferred defects should be declared. These may be acceptable by appropriate actions included in the maintenance schedule.

g. Fatigue:

   i. An audit of the fatigue state helps to establish conformity to the military design standard. It must be established that the accumulated lives of all fatigue life limited components are within their published limits. The Design report should summarise:

      - The document specifying fatigue accounting procedures;
      - Each fatigue critical part/assembly, by name/part number and by serial number fitted at time of initial approval;
      - Life accumulated, life limit, and life remaining of each part as above.

ii. Early types may have fatigue lives quoted in hours, with role factors applicable to different missions or regimes of flight. In this case, the roles presented will be military ones and it will be necessary to assign appropriate civil equivalents to ensure that life accumulated is accounted acceptably. Fatigue lives are usually quoted in Fatigue Index (FI) for modern types. In these cases a fatigue meter will be fitted, recording counts at various manoeuvring load factors. Current practice is to record readings on the fatigue meter as a datum. Where the fatigue meter is unserviceable, fatigue usage will be calculated in flying hours with a suitable factor applied.

iii. Aircraft that have come from former Eastern Bloc countries are likely to have had a different philosophy applied to fatigue lives to that commonly used in the UK or USA for example. These aircraft typically have an overhaul life defined as well as an airframe life. The airframe life is analogous to the fatigue life and may be set at an initial value that is low when compared to comparable Western aircraft. The design authority may then extend the airframe life subject to given conditions being met. Overhaul and airframe lives are frequently defined in the aircraft log book. In such cases, both lives need to be established, preferably with the involvement/concurrence of the design authority, and the aircraft may have to be returned to the manufacturer to have its life extended.

Approval Procedures

A-1.6 The AAN will state that the aircraft/modification approval has been carried out in accordance with the applicable requirements. For UK products, the aircraft approval will be carried out in accordance with BCAR Section A, Chapter A3-7.

Basis Of Approval

A-1.7 **CAA Approval Basis For The Aircraft/Modification**

The AAN will state the basis of approval. Where a military design code is known (e.g. AP 970) it will be quoted (BCAR A3-7 Paragraph 4.1d) although compliance with such a code will not be checked in detail. For Intermediate types approval will also be on the basis of an acceptable safety record and where this is accepted by precedent this is stated. For Complex types the manufacturers statements and exposition undertakings will also be quoted. For a modification approval, a suitable airworthiness code such as BCAR K or CS-23 may be applied.

A-1.8 **CAA Design Requirements For Permit to Fly**

The AAN will specify, or reference a document specifying, the following as applicable:

a. CAA Specifications as applicable
b. CAP 747 Generic Requirements as applicable
c. Equipment requirements.

The AAN will include the following statement:

"Any installed equipment for which the Air Navigation Order requires approval must be approved by the CAA".

A-1.9 **Environmental Requirements**

For an ex-military aircraft operating on a CAA Permit to Fly there are no applicable noise and emissions requirements and so a noise certificate is not required.

A-1.10 **Design Requirements Associated With Operational Approvals**

In general, for an ex-military aircraft operating on a CAA Permit to Fly there are no applicable specific design requirements relating to equipment required by operational rules. However, Schedules 5 and 6 of the ANO 2016 will be reviewed for additional equipment that might be required for the operation. This particularly applies for aircraft used for SSAC operations.

A-1.11 **Compliance With The Basis Of Approval**

A-1.12 **Compliance With The Approval Basis for the Aircraft/Modification**

Two ex-military aircraft ostensibly of identical type may be of significantly differing design/build standards and fatigue states and for this reason the CAA does not consider that it is generally possible to accept one aircraft as series to another. Because of this each aircraft requires an individual investigation culminating in issue of an Airworthiness Approval Note (AAN) specific to it, for approval and initial issue of a Permit to Fly. However, cross referencing to previous AANs for the same type is acceptable in areas where the design/build standard is identical.

The AAN will make reference to the design report defining the build standard of the aircraft, conformity to the type design, manufacturers mods, applicant's mods, Service Technical Instructions, Service Instructions, Mandatory Permit Directives etc. where applicable, as evidence of compliance with the requirements of A-1.8 above.

If relevant, the foreign type certificate will be referenced and how this is applicable to the UK evaluation.

A-1.13 **Compliance With Design Requirements For Permit to Fly**

The AAN will show evidence (or references to evidence) of compliance with the requirements of A-1.9 above. This will commonly include:

a. Equipment approval

b. CAA Specifications

c. CAP 747 Requirements.

A-1.14 **Compliance with Environmental Requirements**

For an ex-military aircraft operating on a CAA Permit to Fly there are no applicable noise and emissions requirements and so no compliance is required to be demonstrated.

A-1.15 **Compliance with Design Requirements Associated With Operational Approvals**

For an ex-military aircraft operating on a CAA Permit to Fly there are no applicable specific design requirements relating to equipment required by operational rules.

A-1.16 **Required (Amendments To) Manuals And Other Documents Including Mandatory Placards**

The AAN will specify, or make reference to a document specifying, changes to the following, where applicable:

a. Flight Manual or Pilot's Notes as applicable – References to documents, CAA approval of them, (and that supplements/change sheets must be included in the AFM)

b. Placards - Actual text, or reference to drawings of placards

c. Electrical Load Analysis - (CAP 747 Generic Requirements 4 and 6)

d. Maintenance Manual

e. Maintenance Schedule

f. Weight and Balance Schedule

The AAN will include a section specifying maintenance manuals and schedule usually by reference to the section on Manuals mentioned above. CAA may agree to a "low utilisation" maintenance schedule. This is intended to catch calendar related aspects/overhauls correctly.

A-1.17 **Conditions Affecting This Approval**

The AAN will detail the Airworthiness Limitations for Permit to Fly as appropriate to the aircraft/modification. These might include that the aircraft must be operated in accordance with the limitations specified in the Flight Manual referenced in Section A-1.17 above, some of which are also defined below.

a. Maximum Number of Occupants
b. Aerobatic Limitations
    i. Whether aerobatic manoeuvres are permitted and specific items that are not, as well as any applicable load factor limitations.
c. Engine Limitations
d. Air Speed Limitations
e. Loading Limitations such as:
    i. Maximum Take-Off Weight
    ii. CG range limits
    iii. CG datum point
f. Other Limitations

i. The aircraft shall be flown by day in visual meteorological conditions only.
ii. Any conditions applicable to the specific aircraft e.g. due to modifications installed.

A-1.18 Continued Airworthiness

The influence of the modification on Airworthiness Directive, Service Bulletin eligibility and other data must be considered and the publications monitored accordingly. The maintenance schedule for the aircraft should include reference to this material additional to the original design.

The AAN will include anything specific such as reduced fatigue life, or any particular inspection/test for continued airworthiness including any additional maintenance or overhaul periodicity including calendar lives, and where the limitation or inspection is to be recorded (e.g. the Aircraft Log book).

A-1.19 Survey

The AAN will state whether a CAA survey is required; and if so, whether the in the particular areas examined during the survey the aircraft was found to conform with the standard recorded by the AAN. Alternatively, it will note that arising from the survey that specified changes are required to the aircraft and documentation.

A-1.20 Issue of Permit to Fly

Each aircraft is required to have a flight test at the end of its restoration. Sometimes this will be conducted by a contracted Test Pilot or delegated to a suitably experienced pilot following a briefing by the CAA on the required Flight Test Schedule. The evaluation is of particular importance for a new type, or one with known marginal characteristics or unusual features. At the end of the test programme the applicant then submits their Flight Test Report to the CAA for assessment.

The AAN will detail the applicable actions that must be completed prior to initial issue of the Permit to Fly:

a. All actions and ground test procedures specified by the aircraft manufacturer must be completed satisfactorily.
b. Verification that the documents or amendments to documents, and the placards defined under Section A-1.17 above are as specified, including any changes specified under Section A-1.20 above.
c. The need for CAA Flight Test
d. Anything else for the specific aircraft

A-1.21 **Approval**

The AAN includes an appropriate approval statement. This will specify that subject to the conditions of A-1.18 above, the aircraft is approved for the issue of a CAA Permit to Fly, provided that it is operated in accordance with the limitations specified/referenced and that it conforms with the contents of the AAN and provided it is maintained in accordance with the Maintenance Schedule as specified in Section 5.5 of the AAN. It also specifies whether the approval is applicable to this example only or may be used on other aircraft of the same type.

APPENDIX 2: Approving aircraft imported in partial of fully completed form

A-2.1 **General**

A-2.1.1 An individual or organisation may apply for a Permit to Fly for a partially or fully completed ex-military aircraft.

A-2.1.2 For a complete aircraft, the eligibility of the imported aircraft for consideration for issue of a Permit to Fly will be subject to:

a. Acceptable documentary evidence submitted by the previous owner to the National Civil Aviation Authority of the country that originally approved the aircraft verifying that the aircraft was certificated/approved as an ex-military aircraft and that it meets the requirements of EU Regulation 216/2008 Appendix II paragraphs (a)(iii) or (d) (Superseded by Regulation (EU) 2018/1139 Annex I); and

b. Acceptable documentary evidence from the National Civil Aviation Authority (or if applicable their Authorised Agents) of the country where the aircraft was originally completed verifying the acceptance of the build standard and quality of restoration of the major components or the completed aircraft; and

NOTE: An Authorised Agent is considered to be an organisation that has formally been given delegated responsibility for the certification/approval of ex-military aircraft by its own National Civil Aviation Authority.

c. The issue of a current domestic flight authorisation (e.g. Special Airworthiness Certificate - Experimental) by the Civil Aviation Authority of the exporting country for completed aircraft; and

d. Comprehensive build/restoration records being supplied with the aircraft; and

e. A full maintenance and repair history with the maintenance schedule that has been used; and

f. Satisfactory compliance with the inspection criteria detailed in Appendix 1; and

g. Evidence being made available that shows that sufficient experience of safe operation has been demonstrated; and

h. Declaration of the design and build standard of the aircraft; and

i. The equipment standard being acceptable; and

j. The flight manual/Pilots' Notes being acceptable; and

k. The GAU Airworthiness Surveyor to agree a bridging inspection for new Permit to Fly based on past history and records; and

l. The completed aircraft being shown fit to fly by means of documentary review, inspection and flight-test.

A-2.1.3 Attempting to show satisfactory compliance with the conditions stated above can be notoriously difficult. If the evidence presented is inadequate then the processing of the application for a Permit to Fly will be delayed or unable to be completed. Some of the points above are discussed in more detail below.

A-2.1.4 Depending on the type, it may be necessary for a BCAR A8-25 approved organisation to carry out a detailed review of the aircraft prior to it being accepted onto the UK register.

A-2.2 Proof of Eligibility

A-2.2.1 Before an applicant completes the purchase of the aircraft it is essential that the documentation described in paragraphs A-2.1.2 a) to l) above, are obtained or ensures that these will be available on completion of the purchase. Also CAA strongly advises the applicant to obtain examples of the build records that will be accompanying the aircraft.

A-2.2.2 When the applicant is in possession of the documents referred to in the above paragraph they should contact the CAA Applications and Approvals Department to make an application for a Permit to Fly. Alternatively, The General Aviation Unit Airworthiness team may be contacted in advance of an application to discuss the project and the likelihood of a Permit to Fly application succeeding.

A-2.3 Maintenance and Repair History

A-2.3.1 The Applicant should be able to present to CAA a verified and comprehensive maintenance and repair history for the aircraft along with the maintenance schedule used.

A-2.3.2 If adequate levels of maintenance and repair history cannot be demonstrated to CAA's satisfaction or the maintenance schedule is considered to be inadequate, then the Applicant may be required to overhaul or re-manufacture the affected parts of the aircraft. This may include carrying out NDT inspections of critical areas of the structure, e.g. welded joints.

A-2.3.3 Before a Permit to Fly is issued to the aircraft, an appropriate maintenance schedule for it will have to be agreed between the Applicant and the CAA.

A-2.4 Approval of the Design

A-2.4.1 The aircraft design will need to be approved or accepted by CAA. As ex-military aircraft are not generally built to a recognised civil standard, each aircraft is treated effectively as a unique case. However, if the aircraft is of the same or similar design to one that has already been previously approved then the process may be simplified and some credit may be given for the previous approval. Once the design has been approved and the build standard and flight test programme agreed the CAA will issue a working draft AAN.

A-2.4.2 It may transpire that as a result of the CAA design investigations additional limitations may be imposed on the aircraft, particularly if the methods of substantiation used in the exporting/original country of approval cannot be verified by CAA. For example, an aeroplane previously flown for aerobatics may now be prohibited from performing such manoeuvres.

A-2.5 Declaring the Build Standard

A-2.5.1 As part of the documentary submission to CAA in support of the application for a Permit to Fly for the imported aircraft, the Applicant will have to declare the design and build standard. The design and build standard consists of a listing of the original drawings used to construct the aircraft, a listing of all modifications and repairs embodied and a listing of all major equipment fitted, such as the engine, propeller, instruments, avionics, wheels, tyres, seat belts etc. The submission should also include the conformity of the aircraft to the declared design and build standard.

A-2.6 Flight Test and the Flight Manual/Pilot's Operating Handbook

A-2.6.1 If the aircraft being imported is a type the CAA has not previously approved then the applicant will have to arrange for a flight test to be conducted by a CAA contracted Test Pilot. If the aircraft is a type previously approved by CAA then the Flight Test may be delegated to a suitable pilot but who will still have to discuss the Flight Schedule with the CAA contracted Test Pilot or GAU Flight Specialist.

A-2.6.2 A Flight Manual or Pilot's Operating Handbook/Pilot's Notes will be required and its content agreed with the CAA's GAU Flight Specialist.

A-2.7 Demonstrating that the Imported Aircraft is Fit to Fly

A-2.7.1 In order to demonstrate that an imported aircraft is fit to fly the following will need to be satisfactorily accomplished and depending on the type; it may be necessary for a BCAR A8-25 approved organisation to carry out a detailed review of the aircraft to achieve this:

a. Have had the Maintenance Organisation satisfactorily conduct the required inspections in order to prove an acceptable level of build quality; and
b. If the aircraft was only partially completed on import, have completed restoration; and
c. For aircraft fully completed on import, have undergone a comprehensive review of maintenance and repair activity as well as successfully completing an annual Inspection in accordance with the accepted maintenance schedule; and
d. Have had the design approved by CAA; and
e. Completed a documentary review for the aircraft to CAA's satisfaction: and
f. Satisfactorily completed an agreed flight test programme.

A-2.8 Aircraft Previously Restored Overseas

A-2.8.1 In each case it will be necessary for the applicant to demonstrate how the approval and system used by the overseas authority might be used as part of the evidence for the design report submission that allows CAA to compile an Airworthiness Approval Note and to progress the application. General points are noted below:

Q1. **Can a warbird with a current and valid US Experimental CofA automatically get a UK Permit to fly with no further showing?**

A1. No. Credit will be given for the Experimental CofA, but the evidence used to get the CofA must be submitted to the CAA with the A8-25 Supplement 2 Design report in order to assist the CAA assessment and for the for issue of the AAN to be progressed.

Q2. **Why does the CAA need to do this?**

A.2 For an aircraft with an Experimental CofA, there is no Type Certificate Data Sheet or established civil design standard, therefore for a UK PtF to be issued there needs to be a known standard to be issued against. The AAN fulfils this requirement and establishes the standard.

Q3. **So the CAA is asking for re-justification of what the FAA has already approved?**

A3. No. The submission to the FAA will be used to establish the baseline design and modification standard at the time of import. However, if the CAA is not content with any aspect – for example a material substitution that it believes may be below strength – then it may ask for a modification to be raised to justify or rectify that issue.

Q4. **What else does the design report and AAN achieve?**

A4. As it is established as a baseline standard, any modifications that are necessary to be made to maintain the aircraft's airworthiness whilst flying in the UK can be recorded as a "delta" from that baseline. This will allow complete records to be maintained both for continuing airworthiness oversight purposes and in the event of an onward sale for the subsequent owner to establish their own baseline standard.

Q5. **CAA and other National Airworthiness Authorities such as the FAA in the USA have bilaterals to allow greater freedom of transfer between registers; why doesn't this apply here?**

A5. Those bilaterals apply to aircraft with established Type Certificates and Manufacturers support. As these aircraft may have neither, the bilaterals do not cover these aircraft and so a standard needs to be established and recorded.

Q6. **My aircraft is certificated in the Limited Category; is the situation different from the Experimental Category?**

A6. Yes, this actually makes the approval process easier because there is an established standard – type basis plus technical orders – with which compliance must have been demonstrated to the FAA. This evidence of compliance must be provided to the CAA and the AAN will therefore reflect that LTC standard plus any deviations/modifications/repairs made from that standard.

Q7. **What else might an applicant be required to submit?**

A7. The applicant and maintenance organisation needs to be able to show how they have satisfied themselves that the aircraft meets the declared standard. The assigned CAA GAU Airworthiness Surveyor will also need to inspect and survey the aircraft before PtF issue. The GAU Flight Specialist will need to be involved in the flight-test phase to approve the test pilot and flight-test schedule and CAA may itself require to fly the aircraft using a contract test-pilot.

A-2.8.2 Most of the aircraft restored overseas come from countries that CAA has close working relationships with. Their systems for approval have been reviewed and their similarities to the UK system identified. This allows CAA to have greater confidence in taking account of submissions made to those Authorities when the aircraft are imported into the UK, however as noted under Paragraph A-2.8 above this is not an automatic acceptance or rubber-stamping exercise. Instead, the similarities in the processes should ensure that the necessary supporting evidence for UK approval is already available as a result of the work undertaken to support the overseas approval. Relevant processes of specific countries are reviewed below:

A-2.8.2.1 **USA**

Ex-military aircraft that are not eligible for a full ICAO compliant Certificate of Airworthiness are instead certificated in either the Experimental category or Limited category.

On import into the UK, the Experimental or Limited Category Certificate of Airworthiness will be given full credit; however, on their own these certificates are not sufficient to allow the CAA to issue a UK Permit to Fly. If the aircraft type required the involvement of a CAMO an A8-25 Supplement 2 submission will have to be made that shows the build standard of the aircraft at the time of import and this should reference the experimental or limited CofA and any applicable TCDS in order to assist the CAA review. The Permit to Fly will be issued against the resulting AAN once the CAA has been satisfied that the established design standard meets UK requirements and that the aircraft has been shown by survey and flight test to meet those requirements.

Relevant or useful FAA legislation and Policy include (but are not limited to) the following:

FAR 21 Certification Procedures for Products and Parts:

Para 33 – inspection and tests;

Para 21.189 – Issue of airworthiness certificate for limited category aircraft;

Para 21.191 – Experimental certificates;

Para 21.193 – Experimental certificates: general;

Order 8130.2J Airworthiness Certification of Aircraft and Related Products: Section 4 (Special Airworthiness Certification), Section 4 (Limited airworthiness Certification), Section 7 (General Experimental Airworthiness Certifications) and Section 10 (certification and operation of A/C under experimental purposes).

Note: Order 8130.2J specifically mentions the bilateral in the context of Type Certificated aircraft and repairs to Transport Category only. It does not apply to non-Type Certificated aircraft.

AC23-27 Parts and Material Substitution for Vintage Aircraft

A-2.8.2.2 **Canada**

Relevant legislation and Policy include the following:

CARS Part V Airworthiness

Standard 507 Appendix F Standards respecting ex-military aircraft.

Standard 509 Exports from Canada

CAR511 Approval of the Type Design of Aeronautical products

Reviewing these, it shows that the same documentation as required by the UKCAA has to be made available to Transport Canada. This documentation should be obtained as part of the submission to the CAA for the AAN and the PtF application.

A-2.8.2.3 **New Zealand**

Relevant legislation and Policy include the following:

Part 21 Certification of Products and Parts:

Para 21.193 Special category – experimental certification requirements

AC 21.3 Product Certification – Airworthiness Certificates in the Special category. This gives useful information including requirements for submissions required to be submitted, such as general design basis plus mods etc. as well as conformity to acceptable type design including aircraft history, aircraft records and data plates

This shows that all data required by UKCAA will have had to be furnished to NZCAA. A copy of the same and the NZCAA inspection record therefore could and should be supplied to UKCAA to support the application.

A-2.8.2.4 **Australia**

Relevant legislation and Policy include the following:

Civil Aviation Safety Regulations (CASRs) Part 21 Subpart H and Regulation 262AM of Civil Aviation Regulations Limited Category aircraft certification.

Civil Aviation Regulations 35/36 – approval of mods and repairs.

CASA AC 21.5(0) Limited category Aircraft – Certification

CASA AC 21.10 Experimental Certificates

In essence, CASA requires the same submissions and documents as CAA for the issue of a Limited CofA. Therefore, when purchasing an aircraft from Australia this documentation should be available to the purchaser and may be used along with a statement of any subsequent modifications as part of the application to the CAA for a PtoF against an AAN compiled on these submitted records.

A-2.9 **Aircraft Previously Exported Overseas from the UK**

A-2.9.1 Confusion has arisen where an aircraft has previously had a configuration approved under an AAN when the aircraft was originally on the UK register. The aircraft then leaves the UK for another register before returning. The original configuration may no longer be reflective of the aircraft's current condition. The receiving organisation, wishing to place the aircraft on the register, may wish to carry out modifications or re-embody modifications to re-establish compliance with the originally approved configuration.

A-2.9.2 Due to the uniqueness of the AAN and Permit to Fly system, unless the aircraft can be restored to its previous UK standard by the application of the same modification standard, using the same materials, components or equipment the original configuration approval cannot be applied. A further modification approval will be required to address the changes, even though they may appear insignificant. This is predominantly an issue for aircraft returning to UK registration. However, if the aircraft has not been altered then the original AAN should suffice.

APPENDIX 3: Standard/non-standard features for ex-military aircraft

A-3.1 Ex-military aircraft often have features not generally seen on type certificated civil aircraft and so may not be catered for by existing civil design codes. The Applicant's design report should contain additional information to cater for this eventuality, in particular for features such as those below.

A-3.2 **Reheat**

A-3.2.1 Aircraft with reheat or afterburner systems will be considered for flight under the CAA Permit to Fly system. The only *intermediate* category aircraft thus far accepted for approval with such a system fitted is the Lim-7/MiG-17 as the reheat fitted is of basic design and also not required for normal operations. Most aircraft with reheat will fall into the *complex* category and therefore the reheat system becomes one part of the whole aircraft that has to meet the applicable requirements under this more exacting category. A good example of this is the SEPECAT Jaguar where the required use of throttleable reheat or the requirement for reheat on the remaining engine in the event of an engine failure renders the aircraft in the *Complex* category.

A-3.3 **Ejection seats**

A-3.3.1 Ex-military aircraft should conform as closely as possible to the standard for which the CAA accepted the service safety record. CAA recommends that ejection seats, canopy jettison systems and Mini Detonation Cords (MDCs) as appropriate should be maintained “live”. For any such “live” pyrotechnic or stored energy system present on an ex-military aircraft in civil operation, data on the system architecture, location, disabling/making safe method etc should be kept by the A8-25 organisation and made available on request by either an airshow organiser in advance, or to the emergency services, AAIB etc in the event of an accident.

A-3.3.2 For CAA to consider accepting that such charged systems as ejection seats, canopy jettison systems and MDCs be disarmed, the aircraft must first be shown to have a landing speed low enough (and with benign handling) that it is reasonable to expect the pilot to be able to make a forced landing in a field.

A-3.3.3 Aeroplanes where disarmed ejection seats have been accepted are all aircraft with seats of low capability (not “zero-zero”), which would not work at the critical parts of the flight envelope – immediately after take-off and prior to landing.

A-3.3.4 Disablement of ejection seats is a modification and as such must be defined (usually via a company procedure) and submitted to the CAA for approval as a (BCAR A2-5) Major Modification.

A-3.3.5 Examples where disarmed ejection seats have been accepted include the Jet Provost Mk 5, DH115 Vampire and Aero L-29.

A-3.4 Drop/Jettisonable Fuel Tanks

A-3.4.1 There are a number of ex-military aeroplanes currently on the UK aircraft register that have the capability to carry additional fuel in external jettisonable fuel tanks for the purpose of enhancing the aircraft's useful range and endurance. The ANO only permits the dropping of fuel or other articles in the event of an emergency. Hence, in principle, such jettisonable fuel tanks could be formally approved subject to investigation of the design of the system to establish that the inherent level of airworthiness was acceptable.

A-3.4.2 The Applicant's design report should address the following aspects:

a. In the absence of known satisfactory in-service experience, the system configuration and the fuel tank latch/release mechanisms should be examined to determine if there are any single failure modes that could cause failure to release or inadvertent release of one or more fuel tanks. If any potential problem areas are identified, review should be made as to whether the probability could be minimised by initiating periodic maintenance checks or by introducing a simple design change. Where the probability of a single failure is assessed as significant, this could be grounds for declining the approval of a particular installation. In order to avoid a single failure causing undemanded jettison, it has been found to be acceptable for second switches to have been fitted in series to the jettison switch.
b. The operating method in the cockpit must require a distinct and deliberate action to release the tanks and must be so located and (guarded where necessary) to minimise the possibility of inadvertent release by the pilot. There must be a placard installed identifying the control, its mode of operation and specifying "emergency use only" adjacent to each cockpit control.
c. Fuel management procedures must be available and published. The original aircraft manufacturers or military operating procedures will normally provide such procedures, but alternate procedures may be approved subject to investigation.
d. The limitations for use of the jettisonable fuel tanks must be established and published in the Permit to Fly. The following must be included together with any other relevant information:
    - Limitations pertaining to the permitted use (e.g. ferry only) if required.
    - Airspeed limitations
    - Load factor limits or limitations regarding permissible manoeuvres with the fuel tanks installed.
e. The modifications in respect of weight and balance, payload etc. must be established and published by amendment to the disposable load section of the aircraft weight schedule.
f. In the case of wing tip tanks or aircraft having more than one tank where they are located at some significant lateral distance from the longitudinal axis of the aeroplane, the implications of loss of one tank inadvertently or failure of one tank to release should be considered in terms of the ability to continue safe flight and landing.

g. The maintenance schedule must include suitable periodic maintenance e.g. lubrication and functional checks, and maintenance to be carried out at installation or removal of the tanks to maintain confidence in the correct operation of what are strictly speaking "one-shot" devices. The one-shot devices are often explosive bolts with a fixed life.
h. Instructions for removal and installation of the tanks should be available and published including the requirement if necessary, to install blanks or covers.
i. The implications of the additional tanks on refuelling procedures and fuel management must be established and the appropriate procedures published. Additional placards may be required in these respects.
j. The Permit-to-Fly for aeroplanes having jettisonable fuel tanks must incorporate the following statement:

   "In accordance with the Air Navigation Order, the operation of the fuel tank release is restricted to emergency use only".

A-3.4.3 **Disablement of Jettison Systems**

A-3.4.4 If the aircraft is to be allowed to fly with external tanks fitted but with the jettison system disabled, the cases to be addressed are performance/engine failure during take-off, ability to recover from spins (with aircraft cleared for aerobatics), and the ability to land with wheels up. These are addressed as follows:

a. For a single engined aircraft, procedures at take-off (particularly at low altitude) usually involve ejection rather than jettison. For twin--engined aircraft this needs review specific to the type.
b. If the aircraft is to be approved for aerobatics, spin recovery needs to be acceptable in all configurations. This is to be checked during flight test for initial Permit issue. Where the Pilot’s Notes show that jettison is required for spin recovery, aerobatics will be prohibited if the tanks are to be fitted but not jettisonable (whether or not they are to be usable for fuel). This is to be recorded on the AAN and Permit.
c. There have been many cases of wheels up landing on empty jettisonable tanks, where the tanks have acted as skids and saved the airframe from damage. In such circumstances, it might be preferable to have empty tanks fitted rather than a clean airframe, although each application will need to be justified on a case-by-case basis.
d. Such a modification is to be covered in a Supplement to the Pilots Notes, the jettison button is to be placarded “Inoperative” and the AAN and Permit to Fly are to record appropriately.

A-3.4.5 **Summary**

A-3.4.6 It is anticipated that use of the above guidelines will encourage a consistent approach to the approval of jettisonable fuel tanks on ex-military aeroplanes. In adopting these criteria, due credit should be given to data submitted which was originated by the aeroplane manufacturer but care should be taken to ensure it is directly applicable to the variant of aeroplane considered.

A-3.5 Occupancy

A-3.5.1 Following an accident in 1986 to a civil registered ex-military aircraft operating on a Permit to Fly, where eleven of the fourteen occupants were killed, the Air Accident Investigation Branch (AAIB) focused attention on the difficulties faced by the CAA in satisfying themselves as to the airworthiness of an ex-military aircraft which has not been civil type certificated and does not have the continued airworthiness support required by ICAO Annex 8 for civil certification. The AAIB recommendation stated that *"When an aircraft is to be operated on a Permit to Fly the Permit should specify the maximum number of seats authorised to be fitted to the aircraft."* The response from the CAA was to define an overall occupancy limit in each case and endorse the Permit to Fly accordingly. The published policy resulted in a number of interpretations of the occupant definitions resulting in a further refinement to the policy in 2009.

A-3.5.2 Normal occupancy Policy: For any ex-military aircraft granted a Permit to Fly in accordance with BCAR Chapter A3-7 Paragraph 4.1(d), which has actual or potential seating provisions for more than two occupants, the maximum number of occupants will be equal to the number of seats fitted or four persons, whichever is more restrictive.

A-3.5.3 Ex-military Transport Aircraft: Some ex-military machines were designed to have capacities of greater than 2 or 4 seats. In such cases additional occupants may be accepted subject to the following defined criteria being met:

a. If the aircraft can be shown to be identical in all significant respects to a similar type which has had, or would have qualified for a Certificate of Airworthiness; and
b. It will be maintained and operated to appropriate standards (equivalent to CofA)

In such cases, the number of occupants may be equal to the number of seats (approved for use during take-off and landing) that were fitted in military service or in civil operation in accordance with a CofA, whichever is the more restrictive. (Reduced occupancy imposed by the civil authorities for the aircraft type, or by the military for the military variant shall be respected). Examples include Max Holste Broussard and Avro C-19/Anson aircraft.

NOTE: Confirmation of the aircraft being shown to be identical to a type which has qualified for a Certificate of Airworthiness would need to be in the form of a compliance statement from the appropriate manufacturer and would have to consider not only the build standard, but also the service experience, maintenance history and component lives associated with the individual example of the aircraft being proposed.

It should also be noted that, a special case was made for Boeing B-17G-105-VE G-BEDF that was assessed specifically to enable carriage of crew necessary to support the aircraft, up to a total occupancy of 6 persons.

A-3.5.4 Modifications to aircraft may provision for alternative occupant carriage and this will be reviewed as a part of the approval process. However, the alternative provisions may not enable additional persons to be carried. For example, the carriage of a person on a seat/pylon attached to an upper wing, occasionally referred to as wing walking, is permitted on suitably equipped aircraft (e.g. Boeing Stearman), but despite there being the provision for three occupant positions, the occupancy limit is still two.

A-3.5.5 Article 71 of the Air Navigation Order 2016 requires that the pilot in command of any aircraft other than a balloon must ensure that each passenger on board occupies a seat or berth and has their safety belt or restraint device properly secured prior to and during taxiing, take-off and landing, and whenever deemed necessary in the interest of safety.

A-3.5.6 Increasing occupancy: The existing restriction has been driven by responses to AAIB reports and recognition of the differing standards between Permit to Fly and Certificate of Airworthiness aircraft. It is therefore essential that to increase the occupancy and still retain a Permit to Fly, mitigation or additional considerations have to be put in place over and above the existing Airworthiness Approval Note (for pre-approved aircraft) or as part of the AAN development for new applicants to keep the risks associated with the increased occupancy of the aircraft to tolerable levels.

A-3.5.7 Increased Occupancy Policy: For individual aircraft on a case-by-case basis it may be possible to increase the occupancy of an ex-military aircraft of military design on a Permit to Fly above the maximum of 4 persons,
This is intended to enable ex-military aircraft to demonstrate an equivalence to the approach taken for aircraft of a type previously Type Certificated and operated on a Certificate of Airworthiness which were downgrading to a Permit to Fly, such as the Max Holste Broussard and Avro C-19/Anson, the first example of this compliance demonstration being undertaken for a Bell UH-1H helicopter.
To increase the aircraft occupancy:

a. adequate seating and provisions must exist,
b. occupancy may increase to a maximum 3 crew plus six additional occupants,
c. occupancy may increase to a maximum permissible occupancy of nine.
d. The objectives set out in the paragraph A-3.5.8 below are satisfied.

A-3.5.8 Objectives to enable Occupancy increase: The aircraft maximum occupancy is specified on the Permit to Fly and within the Airworthiness Approval Note as a limitation. To alter this limitation, a Major Modification (classified in accordance with BCAR A8-21 appendix 2 Para 3.3.5) shall be applied for, and a report submitted by an appropriately approved Design Organisation (in essence either the original manufacturer [OEM] or an BCAR A8-21 organisation) to substantiate the occupancy increase/change to the Permit limitations.
The approved applicant for the Major Modification will provide a design report to substantiate an appropriate level of airworthiness broadly equivalent to that of a

type certificated aircraft in the areas defined below, addressing the risk mitigation measures introduced to permit the requested increase in occupancy. This shall include:

a. An assessment of, and if necessary required changes to, occupant safety provisions in terms of:
    i. seating configuration (potentially including restricting seats in aeroplanes to fore-and-aft), seat design,
    ii. crashworthiness,
    iii. head impact criteria
    iv. fire detection and
    v. emergency egress (including exit provisions, operation and placarding and a demonstration of the occupant's ability to egress each aircraft in the event of an emergency in which the crewmember(s) is unable to assist)
b. Means to manage and control the movement of occupants around the aircraft and ensure the need for them to be seated with harness fastened when necessary, e.g. during taxi, take-off and landing, and in turbulence.
c. The identification of the crew necessary to manage additional occupants, who shall be defined as in-addition to essential flight crew.
d. The investigation will consider the reported risk mitigation measure presented within the design report and a cabin inspection (survey) will be conducted to verify conformity.

A-3.5.9 Ex-military aircraft shall have a placard in the cabin with the following warning to the occupants

"This aircraft has not been certificated to an International Requirement"

A-3.6 Use of ex-military livery and serial numbers – Exemptions from the need to display Marks on UK Registered Aircraft

A-3.6.1 Article 32 of The Air Navigation Order 2016 states that aircraft registered in the United Kingdom shall not fly unless they bear the nationality and registration marks allocated by the CAA.

A-3.6.2 In certain cases exemptions to Article 32 are granted for aircraft to fly without bearing UK nationality and registration marks. The CAA Aircraft Registration section policy is only to exempt aircraft which display historically accurate military liveries and marks. The exemption is usually issued for a period of three years and should be renewed on expiry if the aircraft is to remain in those markings

A-3.6.3 If the aircraft is to bear military markings permission must be obtained from the Ministry of Defence or the appropriate foreign government and sent to the CAA, Aircraft Registration section. One exception to this is aircraft wearing United States military markings as the US Embassy have granted permission for UK registered aircraft to wear their authentic markings as long as the aircraft type is no longer in USAF use or in their service inventory. Permission of the UK MOD should be sought from the RAF Events Team at RAF College Cranwell. Other permissions should be sought from the Embassy of the relevant country concerned or direct from the relevant military air arm.

Note: The normal letter of permission issued by the UK MOD excludes flights in Northern Ireland and outside of UK airspace and gives permission to the applicant rather than the aircraft which may change ownership in the future. A new owner of an exempted aircraft should re-apply to the MOD for their permission to maintain these markings under new ownership. Once an exemption is issued by the CAA it should also be noted that this allows the flying of the aircraft in UK airspace only, if the aircraft is to be flown outside the UK then extra permission must be sought from the authorities of the countries visited or over flown.

A-3.6.4 To apply for an exemption from the requirements to display nationality and registration marks application should be made to the Aircraft Registration section. The CAA Aircraft Registration section also requires the following information in support of an application for the exemption:

i. A current colour photograph or photographs clearly showing the livery and marks carried by the aircraft concerned, or a colour diagram showing the intended livery and marks to be carried by the aircraft concerned.
ii. Literature (which includes diagrams or pictures) on the aircraft which would allow the Aircraft Registration Section to verify the authenticity of the livery carried by the aircraft; and

Once an exemption has been granted, any changes to the markings displayed on the aircraft must be notified immediately in writing to the Aircraft Registration section.

A-3.7 Airworthiness Requirements for Aerobatic Smoke Systems

A-3.7.1 The following requirements apply to smoke systems fitted to ex-military permit to fly aircraft. They are equally applicable to civil aerobatic machines.

a. Weight
   The definition of empty weight for the aircraft shall include the weight of the smoke system but exclude that of the fluid. The aircraft must remain within the existing weight and centre of gravity limits.
b. Strength
   The smoke system shall be stressed to withstand the same load cases to which the aircraft was designed, including the manoeuvre, gust and emergency alighting cases.
   Guidance Material: The stressing submission need only cover additionally installed parts associated with the smoke system. Conservative load factor stressing assumptions may be made which may obviate the need to establish specific load factors.
c. Cockpit

The cockpit controls shall be located such that the pilot, when seated, strapped in and in full flying kit, has full and unrestricted movement of each control. The cockpit shall have adequate ventilation.

Guidance Material: A CAA pilot may carry out a cockpit assessment to assess qualitatively the air quality in the cockpit.

d. Smoke Fluid Tank Design and Installation

   Each tank shall withstand without failure the vibration, inertia, fluid and structural loads that it may be subjected to in operation. Each conventional metal tank shall be pressure tested to 3.5 psi.

   The smoke fluid tank filler connection shall be electrically bonded to the aircraft structure. Any vent system shall be vented to the exterior of the aircraft.

e. Lines fittings and components

   The lines, fittings and components shall conform to good engineering practice and be compatible with the fluids to be used.

f. Smoke fluid

   The smoke fluid specifications are to be established for the system. The system shall be configured in such a way that the possibility of accidental filling with AVGAS or any other inappropriate fuel is unlikely.

   Guidance Material: The filler neck may be fitted with a restrictor to ensure that a normal AVGAS refuelling nozzle cannot be inserted. A suitable placard may be accepted in lieu of an undersized filler neck.

g. Miscellaneous markings and placards The smoke tank filler connection shall be placarded with the approved smoke fluid specification and the usable capacity of the tank. System controls should be appropriately placarded, this placard also conveying any operating limitations

h. Fire Safety

   i. Particular attention must be given to the requirements of CS 23.1121(b) with respect to the smoke fluid line that introduces the smoke fluid into the exhaust system.
   ii. In order to minimise the probability of an unsafe operation, it must be demonstrated that under the critical operating conditions, there is no risk of ignition of the injected smoke fluid either within or external to the exhaust system.
   iii. Unless it can be shown that there is no possibility of a fire under normal or failure conditions, it must be shown that the flow of smoke fluid can be stopped to prevent further smoke fluid reaching the exhaust system.

i) Flight Manual Supplement

   The Applicant shall provide a Flight Manual Supplement, prepared in accordance with BCAR Section K Chapter K7-5, Appendix 5.

A-3.8 Other Special Features – General

A-3.8.1 There are many features which may be found on military aircraft, which are not usual in General Aviation civil aeroplanes. These often come to light during the review for potentially hazardous features referred in BCAR A3-7 Paragraph 3.1

(d). Assessment of new features calls upon the Surveyors experience and judgement. Although the CAA is not the design authority of such types and must not re-design them, there may be features which place third parties at unnecessary risk, and fundamental principle of proof against a single failure must be borne in mind. Some examples of special features previously addressed are detailed below.

A-3.9 Armament

A-3.9.1 Ex-military aircraft must not be armed. Guns may remain fitted for authenticity and to retain c.g. position, but they must be disabled.

A-3.9.2 Replica bombs will be considered for fitment on a case-by-case basis as they may need justification of the loading conditions. Handling and performance may also be affected and assessment of these will have to be made and reflected in the Pilot’s Notes.

A-3.10 UK Instruments

A-3.10.1 Although metric instruments are not unusual in aircraft with overseas service history, for UK civil operation:

a. Altimeters must be to UK standard (ft. and millibars)
b. ASIs may be in any units but must be consistent with the Pilot’s Notes employed (use of RAF Pilots Notes in lieu of may thus drive change in ASI)

A-3.11 Simulated failure modes selectable from Rear Cockpit

A-3.11.1 It should not be possible to select simulated failure modes such that the commanders (P1) level of control over the aircraft is reduced. In cases where this is possible in service, these have been identified and rendered safe. This method was employed in such as the Aero L-39 Albatross.

A-3.12 Jettisonable Doors

A-3.12.1 Jettisonable doors are not usual on aeroplanes although they may be an integral part of an ejection system (e.g. Canberra rear seat). On the P-63 Kingcobra the doors are designed to be jettisonable for emergency use, via withdrawal of the hinge pins at the leading edges. In this case in order to reduce the possibility of inadvertent jettison, the CAA required a frangible copper wire seals at the pin ends, as a “tell-tale”. It therefore remains possible to jettison such doors.

A-3.12.2 Jettisonable doors are usual on military rotorcraft and no measures such as mentioned above have been taken.

A-3.13 Bomb Bay Doors

A-3.13.1 Aircraft such as the Canberra and Vulcan have a large bomb bay and the doors may be opened in flight. The deployment in flight of such doors is part of the normal operation of the aircraft and is generally accepted as such, within any limitations quoted in the Pilots Notes. However, a restriction may be placed on this due to some system location changes to allow for such as an experimental equipment fit that was removed prior to civil operation.

A-3.14 Arrester Hooks and Catapult Launches

A-3.14.1 Arrester hooks intended for use during ship-borne or ground based operations may be fitted for authenticity. The use of arrester hooks is not required for civil use and is not approved. A limitation will appear on the AAN and on the Permit in such cases. Similarly, although the necessary equipment to conduct catapult operations in military service may be fitted for authenticity, the use of such gear has not been approved for civil use as it may involve additional stresses on the airframe and difficult handling cases for the pilot.

A-3.15 Brake Parachute

A-3.15.1 If a brake parachute was fitted during military service, this is allowable provided it is adequately covered by Pilots Notes. It should not be streamed in flight (although CAA does not insist on a weight-on-wheels switch) and it is not to be relied on in order to plan a landing on a short runway.

A-3.16 Operation from Grass/Unpaved Surfaces

A-3.16.1 Most turbine-powered aircraft were designed to operate from prepared hard surfaces (runways or carrier decks). Operation from grass fields is prohibited for such aircraft unless the Pilots Notes/Aircrew Manual specifically allows it, as such operations may affect fatigue life. A Mandatory Permit Directive (MPD) was necessary to clarify this aspect for the Jet Provost. The L-39 may operate from grass provided the weight is within an acceptable limit.

A-3.17 Electric Trim only, without back-up actuator

A-3.17.1 On the L39 the elevator trim is electrical only, with no back-up actuator. Flight test assessment concluded that in the event of failure leading to runaway the control forces are light enough that the pilot could still be expected to land the aircraft.

A-3.18 Automatic Deployment of Controls

A-3.18.1 On the L-39 the airbrake automatically extends if both Mach meters read more than 0.78. That both have to detect such a condition provides some protection against inappropriate deployment due to a single failure. In this case flight test assessment of trim change due to deployment at low speed concluded that the pilot should be able to cope with un-demanded deployment in the circuit.

A-3.19 Transmission Tunnel

A-3.19.1 On the P-39 Airacobra and P-63 Kingcobra the engine is mounted behind the pilot, who sits astride a transmission tunnel, which houses the drive to the tractor propeller. Although at first sight this unusual design appears alarming, it is a feature that is accepted as part of the overall design without further investigation. However, as the engine is behind the pilot an engine fire warning system may be installed as an applicant’s modification to give an additional level of safety.

A-3.20 Coffman or AvPIN Starters

A-3.20.1 Ex-military jets such as Hunter, or Canberra may employ cartridge-powered starters or iso-propyl nitrate powered starters. While these systems present an increased hazard for ground handling, they do not present an unacceptable level of in-flight hazard, and have been accepted as they are (with the appropriate life limits on the equipment concerned).

A-3.22.1 It should be noted that some aircraft – such as the Hunter – have been modified to have an electric starter to negate any issues with the previous type of starter.

A-3.21 Flight in IMC

A-3.21.1 The Permit to Fly generally restricts flight to day VMC only. On occasion, permission for limited flight in IMC has been granted on an individual basis for ex-military aeroplanes of a type that were approved for such flight in military service. For any formal approval to operate in IMC, the aircraft operating company will have to make a suitable justification for consideration by the CAA. The necessary (Major) Modification will have to demonstrate that the aircraft is equipped for the flight and that the safety record of such operation in service supports such operations, recognising that this will affect the limitations imposed by the Permit to Fly including those associated with geographical overflight restrictions. Consideration will be given on a case-by-case basis only and any modification's approval will not be taken as a precedent for other types and/or other classes of permit to fly aircraft.

A-3.22 Hazardous Materials

A-3.22.1 Operators of ex-military aircraft, particularly those involved in flying displays must identify and where practicable (i.e. where this does not adversely affect airworthiness, such as by restricting fuel capacity such that it is a risk increase in itself) consider removal of hazardous materials such as phenolic asbestos. Where removal is not practicable, data on the material type, location etc should be kept by the A8-23,4 or 5 organisation as applicable and made available on request by either an airshow organiser in advance, or to the emergency services, AAIB etc in the event of an accident.

APPENDIX 4: Applicant procedures for A8-25 supplement 2 organisations in support of ex-military aircraft permit to fly applications

A-4.1 **Introduction**

The purpose of this appendix is for guidance of a company's personnel, when engaged in the process of application for a Permit to Fly.

A-4.2 **Procedures**

The following sample procedures cover submission of an aircraft to the CAA for initial issue of a Permit to Fly.

A-4.2.1 Procedure for the Application to CAA for initial issue of a Permit to Fly and submission of Justification for this. The Chief Engineer is responsible for carrying out the company aspects of this procedure.

a. Raise permanent company record file on the aircraft
b. Application to register the aircraft in the UK is made on CAA Form CA1 together with payment.
c. Application is made on Form CA3 together with payment for the deposit. This is sent to CAA's Shared Services Centre (SSC) at Aviation House, Gatwick. If the CAA has not previously accepted an example of the type, the A8-25 Supplement 2 Signatory will propose a complexity category at the time of application and include sufficient information on the design features of the type (technical descriptions and Pilots Notes) to justify the recommendation with his letter.

If the aircraft is of a type previously accepted by the CAA:

d. Obtain copies of previous AANs to ensure that all aspects are covered in the design report. Then proceed to Paragraph (g) for complex aircraft or Paragraph (i) otherwise

If the aircraft is of a type which has not previously been accepted by the CAA:

e. If the aircraft complexity categorisation is marginal, or if it incorporates features not previously accepted by the CAA, further meetings may be required (if necessary at Aviation House) in order to determine acceptability. The Chief Engineer will arrange such meetings and compile appropriate presentation material.
f. Submit safety record (BCAR A3-7/B3-7 Appendix 1 paragraph 2.1) and any proposed improvement measures for civil operation to CAA Design Surveyor for discussion and agreement.
g. Obtain formal written acceptance of the type complexity category and safety record (with improvement provisos) from the CAA.

Once the safety record and complexity category have been agreed by the CAA:

If the aircraft is classified as *Complex*:

h. Obtain the manufacturer(s)' (OEM(s)') formal agreement to remain involved in the continued oversight of the project. A contract to provide the necessary support arrangements is expected to be in place for this (see CAP 553, BCAR A8-25 Supplement 2 paragraph 3.4). Propose Exposition content to cover procedures for the manufacturer(s)' continued airworthiness support* for the aircraft, engine(s) and of its critical systems and equipment. [Note: BCAR A8-25 Supplement 2 Appendix 2 paragraph 3.4.1 allows an *'equivalent organisation suitably (CAA) approved for this purpose'* (of continued airworthiness support*) to assist the A8-25 organisation in presenting and supporting the aircraft for the duration of its civil operation.] *[*Continued airworthiness support* should be taken here as meaning the provision of type-related subject matter expertise in relation to both the initial preparation and presentation of the classification and in-service safety data, and the provision of a level of through-life-total-support (ref. paragraph 1.15 above) appropriate to its specific features and characteristics. This expertise is expected to relate to both the type's original design and in-military service modifications and its manufacturing and testing/qualification criteria.]

i. Obtain CAA approval of such procedures and Exposition amendment.

Otherwise:

j. Establish conformity to type design standard for which the safety record was demonstrated, via checklists against modifications required for airworthiness. Compile a design report (referring to subsidiary documentation including modification check lists, fatigue audit, etc) to show that the particular aircraft matches the design standard for which the safety record was generated. This must also identify and propose technical justification for any departures from this standard (see procedure 6.2 for more detail).

The bulk of the permanent company records covering justification will be completed at this time.

k. Send design report to CAA GAU Design and Certification Surveyor at Aviation House, Gatwick, together with other supporting information as necessary (such as a copy of each applicant's modification, copy of Pilots Notes, FRCs, Release To Service document, Operational Data Manuals etc).

l. Provide responses to the GAU Surveyor's questions relating to the aircraft/submission.

m. Propose flight test schedule and test pilot and obtain CAA agreement to each of these. Ascertain whether the CAA requires to fly the aircraft. CAA Flight Specialist assessment will always be required for a new type.

A-4.2.2 Procedure for Compilation of a Design Report

The company design report should employ a similar layout to the AAN issued by the CAA as per Appendix 1. The A8-25 Supplement 2 Signatory should compile a report and ensure that permanent company records are compiled concurrently. Copies of supporting documents such as Aircrew and W&B manuals, AP extracts etc. should be included.

A-4.2.3 Modifications not shown on the Manufacturers Master List including those made by the A8-25 Organisation

The Supplement 2 approval granted under BCAR A8-25 approval does not confer approval of any activity to design or seek approval for Major Modifications on this class of aircraft.

While the aircraft should conform as closely as possible to the Type Design Standard in respect of which the safety record has been accepted, the CAA recognise that the operating organisation may wish to embody modifications in order to simplify operation of the aircraft (such as replacement of non-standard oxygen supply connectors with NATO standard connectors).

In general, the normal CAA procedure as detailed in BCAR A2-5/B2-5 will apply in such cases. Significant changes to the aircraft in terms of powerplant changes, propeller type, alternative material specifications or equipment changes (to ensure that the aircraft is equipped to a standard acceptable to the CAA for the intended purpose) may be the subject of major modification action. Such modifications are to be adequately defined on modification sheets to include drawings, circuit diagrams and changes to Pilots Notes showing effect on limitations and operation, and justification.

The design report will list modifications but procedure for justification of each will be subject to individual agreement with the CAA Design and Certification Surveyor. Use of appropriate approved design organisations is normally required for particular modifications such as those affecting primary structure.

Minor modifications to aircraft or components are required to be submitted either to the GAU Airworthiness Team, along with technical justification, to substantiate such change or alternatively be submitted via a suitably CAA approved design organisation.

APPENDIX 5: Changes to the original design

A-5.1 Introduction

The purpose of this appendix is for further guidance regarding changes to the original design standard of an aircraft.

A-5.1.1 A modification is a change made to an aircraft or its engine, propeller, radio apparatus, accessories, instruments, equipment, and their installations. The changes may be made during restoration of an aircraft (either in the UK or prior to transfer to the UK) or during in-service maintenance. These changes may include:

a. Substitution of one type for another when applied to components, engines, propellers, radio installations, accessories, instruments and equipment.
b. Material substitution, changes of processes or treatments during the manufacture of replacement parts.
c. Addition, removal or alteration of components.
d. Any repairs not made in accordance with a manufacturer’s repair manuals or other approved repair schemes.
e. Changes to the aircraft that affect the flight manual or maintenance manual.

A-5.1.2 Operators should ensure that all changes (including repairs) made to the aircraft are included in the aircraft records and have the necessary (major or minor) modification approvals in place where required. Where required, operators should establish that all parts used in support of these activities have been manufactured in accordance with appropriate approved design data.

A-5.1.3 If it is not possible to establish the applicable approval for a modification or repair, operators should contact the General Aviation Unit Airworthiness Team for further assistance and guidance.

A-5.2 Guidance

A-5.2.1 Standard Modifications

Generic guidance to applicants who do not hold CAA BCAR A-8 or CAA Part 21 Design Organisation approvals, for the preparation of the data required to support applications for the approval of minor modifications to UK registered non-EASA aircraft has been developed and published as CAP 1419. This reflects also the guidance given by EASA within CS-STAN.

A-5.2.2 Standard Repairs

Generic guidance regarding standard repairs is also addressed by the inclusion of CS-STAN under CAP1419 as mentioned in A-5.2.1.

A-5.2.3 **Material Substitution**

Generic guidance regarding materials substitutions is being developed as part of the GA Programme. At the conclusion of this item, the relevant information will be included here.

A-5.2.4 **Manufacture of Spare Parts and Assemblies**

With the introduction of BCAR A8-23 (specifically Paragraph 9.3) and A8-24 (specifically Paragraph 5.1), the ability for suitably approved organisations to manufacture or fabricate components and assemblies has been introduced. A capability list and procedures for this should be included in the company exposition for agreement and approval by the assigned GAU Airworthiness Surveyor. Guidance and Advisory Material will be developed in relation to this and included within this CAP when available.

APPENDIX 6: Ageing aircraft campaigns

A-6.1 Introduction

Chapter 5 recognises that in some cases there is a shortage of information on ageing aircraft systems and wiring, particularly in ex-military aircraft. Where extensive restoration has taken place, the original components will have been refurbished and perhaps wiring replaced. However, there are many instances where little has been done to the aircraft and its original build standard. Guidance will be therefore established for ageing aircraft, system and included within this Appendix.

A-6.2 Guidance

A-6.2.1 Engine Overhaul Lives

Guidance will be provided here on engine overhaul lives in a future revision to this CAP.

A-6.2.2 Corrosion

Corrosion can result in a significant decrease in the thickness of original load bearing material that can lead to a loss of structural integrity and potentially to catastrophic failure. In the case of more highly stressed parts, finding and rectifying corrosion damage can help to prevent the early initiation of fatigue cracking from corrosion pits that can also lead to premature structural and catastrophic failures. This has been observed in aluminium alloy forgings and light aircraft landing gear components, where a mixture of exfoliation and pitting corrosion on the flash line initiated stress corrosion cracking that then lead to corrosion fatigue, normal fatigue and exfoliation.

To aid in dealing with this, general guidance is provided in CAP 1570 on the design, assembly and inspection of various parts of an aircraft structure. Those areas that because of their remoteness, complexity or boxed-in nature and are not readily accessible during routine maintenance or require attention in the light of operational experience are highlighted.
http://publicapps.caa.co.uk/docs/33/CAP1570_Corrosion.pdf

A-6.2.3 Electrical Wiring

Guidance on the condition of wire and wiring materials found in British ex-military aircraft, built in the World war II and Post-war period flying with a Permit to Fly, has been generated by Mr Cartwright of Airwire Vintage aircraft wiring specialists. Permission was given by the author for CAA to make use of this material, and it is therefore presented as Appendix 7 to this document.

A-6.2.4 Component Lives

Guidance on the condition of components, such as seals etc. and ancillaries such as fuel and air system components where the continuation of an hourly-based inspection/replacement regime does not account for a potential degradation of the seal material due to system inactivity or the resulting calendar period will be provided here in a future revision to this CAP.

A-6.2.5 Seat Harness Condition Monitoring

EASA has published a Research Study into seat belt degradation:

https://www.easa.europa.eu/system/files/dfu/SEBED%20Report_Final_5-2010.pdf

Further guidance on the condition of seat harness and components was published by the CAA in Safety Notice SN-2019/003:
https://publicapps.caa.co.uk/modalapplication.aspx?catid=1&pagetype=65&appid=11&mode=detail&id=9025

APPENDIX 7: Ageing aircraft Wiring

AIRWIRE *Vintage Aircraft Wiring Specialists*

Report on the condition of wire and wiring materials found in British ex-military aircraft, built in the World War II and Post-war period, (for Permit to Fly).

by

Ben Cartwright

Report AW/2002/1

Issue 4

2017

ISSUE 1

Issue 1 of this document was written as a report, submitted to the CAA, to highlight certain problems with aircraft ageing wire installations, encountered by the author during aircraft restoration or rebuild projects. The CAA subsequently issued it, to their aircraft engineering surveyors, for reference purposes.

Oct 2001

ISSUE 2

Issue 2 of the document was written, following further research, to expand on some of the topics already covered and to introduce new topics.

June 2002

ISSUE 3

Issue 3 was written, with further experience of a wider range of aircraft types. Illustrations have also been introduced to expand the information.

The title has been amended to "Report on the condition of wire and wiring materials found in British ex-military aircraft, built in the Post-war period", having previously been limited to "built in the 1950s and 1960s".

Sep 2010

Issue 4

Issue 4 incorporates further changes to give more information and improve the presentation.

Jul 2017

AIRWIRE *Vintage Aircraft Wiring Specialists*

Airwire is the trading name for the author's company, which provides a re-wiring or wiring repair service to organisations and individuals involved in the restoration or rebuild of older aircraft. Airwire specialises in British and American ex-military aircraft, which are now privately owned and operated but also covers older civilian aircraft.

Table of contents

Report on the condition of Wire and wiring materials found on British ex-military aircraft, built in the post World War II period

Introduction

This report was written to raise the matter of the inspection and assessment of the condition of electrical wiring*, (in particular Pren and Nyvin wire*) and wiring components, during rebuild or restoration programmes, specifically relating to British-built military aircraft, built during post-World War II period. It is hoped that it will provide a degree of background knowledge and some indication of the problems and potential consequences that may be encountered and should be rectified, when these types of aircraft are submitted to inspection for a Permit to Fly.

The information is drawn from the author's involvement with aircraft restoration and rebuilds programmes, carried out between 1990 and to date. The author's prior background also includes: military aircraft maintenance, *(1963 to 1985)* and cable harness design and manufacture *(1986 to 1990).* It is based on work carried out on a wide range of British military aircraft types. Although based mainly on experience with military aircraft, the detail will read across to civil aircraft, of a similar period, which utilised the same types of wire and wiring systems and whilst specifically addressing British wire and equipment, the general problems discussed will apply to all aircraft of a similar age.

The period, referred to, in the title of this paper, covers the mid-1940s to the 1960s, during which various aircraft types would have been in production and service, but the comments may equally apply to earlier and later periods. Where suggested dates are given for the introduction of newer materials, these have been taken from consulted reference material. The topics discussed below are drawn from a wide range of aircraft and are not intended to be specific to any one type. Whilst specific to British aircraft, the general principles of this document, will apply across other Nations aircraft, such as the USA. Occasional references to American equipment are given, where relevant.

The terms cable and wire are often considered to be interchangeable, although cable is usually used to describe a number of wires contained in an overall jacket, either by manufacture or assembly. For this report the term "wire" and "wiring" have been used, except where "cable" is the more commonly used terms; e.g. "Cable clips", "Cable harness" and "Cable ties".

Where possible, reference is made to RAF/Air Ministry Air Publications, (AP), which are accessible in the RAF Museum at Hendon. In some cases, the information may be duplicated, in other APs.

SBAC Standard Wiring System

Development of aircraft production, prior to and during World War II meant that many aircraft manufacturers developed their own wiring systems. Towards the end of the war, standardisation of electrical wiring systems became an objective for the British aircraft industry.

The first attempt at industry standardisation was the SBAC *(then the Society of British Aircraft Constructors)* Standard Wiring System, which began to appear in production in 1944 and was further developed post-war. This used standard terminal blocks, known as Connector blocks and multiple-unit fuse blocks to interconnect wiring around the aircraft. The method of securing the wires to components was a direct development from the Lucas-Supermarine Wiring system, used on Spitfire fighter aircraft. The system also used both individual and multi-core cable runs, with minimal use of multi-pin connectors; which were usually restricted to connections to wing junctions or equipment boxes. At the same time, the use of single pole wiring systems, with the metal fuselage providing earth returns, to replace earlier two pole systems, which had been necessary on wooden framed or fabric covered aircraft, became the norm.

The smaller gauge wires were terminated in ferrules, which were then secured into a two-part clamp contact at the termination points. Larger wires used conventional terminal posts and ring terminations. Wires to items of equipment were terminated with ring terminals onto stud or screw type terminal blocks, or into proprietary, small multi-pin connectors. Some aircraft manufacturers, such as Avro and Vickers, used their own system of terminal blocks, for the general aircraft wiring, but followed the SBAC principles.

The individual wires would be drawn and tied together into harnesses, but not generally over-sleeved; this being reserved for areas where there was a risk of damage to the wires. Wires runs could be contained in ducting, (metal or plastic box section channels), which was favoured by certain aircraft manufacturers, *(but not by others),* or in conduit tubes. It was relatively easy to repair or modify circuits. Problems with the development of smaller terminal block systems, however, led to this system falling out of favour and being overtaken by the Plessey Wiring System, which was developed in parallel, for military and civil aircraft.

The SBAC system initially used mainly Vin, Cel or Rubber wire, which were all superseded by Pren wire, *(all discussed below),* as well as other special purpose wires.
A more detailed description of the Standard SBAC Wiring System may be found in Air Publication, AP 4343C, Book 3, Section 5, Chapter 2.

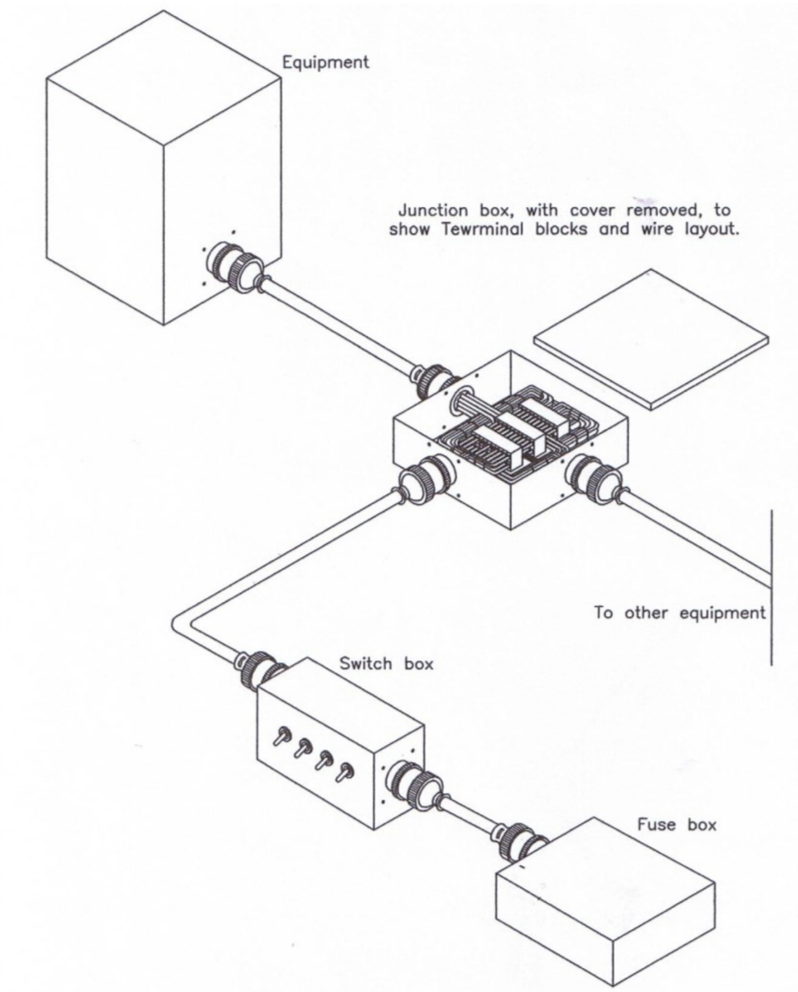
Plessey Wiring System

During the late 1940s and 1950s, the Plessey Company, as a sub-contractor to many aircraft manufacturing companies, built wiring systems for British military aircraft. Other companies, such as Rists, Lucas and BICC, also provided a similar service. Most, but not necessarily all, military aircraft of the time were built to the Plessey Wiring System. This used cable harness assemblies; designed around multi-pin connectors attached to junction and fuse boxes, which contained terminal blocks and fuse blocks, for interconnecting wiring around the aircraft. *(See Fig. 1).* The aircraft wire harnesses and the boxes were produced so that each part was replaceable as a single item. The harnesses were often built with PVC over-sleeving, which could be sealed into the connectors at either end, to make give extra mechanical protection to the wires and make them “climatic-proof”. It was also designed to prevent the formation of water ice, with high altitude flying, causing problems inside connectors. Standard multi-core cables were used for local distribution to items of equipment, The design meant that installation of wiring harnesses was relatively easy and that harnesses or units could, in theory, be removed from an aircraft and quickly replaced by another harness or unit, whilst repairs to the original could be carried out at relative leisure. This was a legacy from World War II, where speed of production and repair to battle damage had been a major factor. This method was, however, very costly and modifications and minor repairs were not easy to incorporate.

The Plessey Wiring System, nevertheless, became the preferred method of wiring for military aircraft and remained the standard for military aircraft, until about 1960.
In some aircraft installations, however, aspects of the two systems*, (SBAC & Plessey),* appear to be used in combination, as well as aspects of individual aircraft manufacturers systems.

The Plessey system initially used mainly Vin and Rubber wire, which were then superseded by Pren wire, *(discussed below),* as well as other special purpose wires.

Figure 1 - Examples of Plessey Wiring system components



A detailed description of the Plessey Standard Wiring System may be found in Air Publication, AP 3275A, Section 1, Chapter 2.

Later Wiring Systems

By the 1960s, later wiring systems had evolved, which followed the principles of the SBAC system, in the use of harnesses made up of individual wires, but with much greater use of circular connectors, *(to both British and American specifications).* There was also the introduction of what were initially called Vickerstrip, but were eventually and commonly known as Ward-Brooke terminal blocks and also Nyvin wire, for general-purpose wiring. Fuse blocks were replaced by individual fuseholders, to various designs. This was due to current flow causing localised heating within multi-fuse fuseblocks, leading to distortion and breakdown. Standardised terminals, initially manufactured by Hellerman and later by AMP, were brought into use. There does not appear to have been a formal “System” name.

The ducting and sleeving methods of routing and protecting cables, introduced by the two earlier systems, were dropped and replaced by more open, but well supported wiring runs, except where there was a specific requirement for localised protection.

Wire types - Rubber, Cel, Vin and Genmet

As a result of standardisation, brought about by the requirements of aircraft production during World War II, these were the main aircraft general purpose wires in use at the end of the war and remained so, until the introduction of Pren wire. There were, however, many other types of wire in use, for specific applications.

Rubber wire, which used Vulcanised India Rubber, (VIR), as the insulation and Cel wire, which used a varnished cotton braid over VIR insulation, were used in many British war-time aircraft. Both wire types now suffer from deterioration of the VIR, with age and contamination and the Cel outer insulation tends to harden and become brittle.

Vin wire, which uses a brown PVC jacket over VIR insulation, replaced both types by the end of the war. Vin wire has been seen in some aircraft, which were built in the early 1950s, well after the introduction of Pren wire, presumably as existing stocks of Vin wire were consumed. Vin wire tends to suffer from hardening of the PVC jacket and deterioration of the VIR at exposed termination ends.

Genmetsheath wire was specifically used for generator output cables. It consisted of VIR insulation over the conductors, a wrap of varnished cambric tape, an extruded TRS (Tough Rubber Sheath) jacket and finally braided with tinned copper wire, for electrical screening. This wire type would be fitted between the generator and a suppressor or filter unit, which was used to eliminate electrical noise from the generator system, which would have caused radio interference. Another variation called Gensheath, without the overall screening, was used between the filter and the rest of the generation system. Because of its use in engine areas, both types of cable are often oil soaked and whilst there is some degradation in physical appearance, the outer jacket is usually in good condition. However, the major area of concern is the disintegration of the exposed VIR insulation at termination ends. It remained in use, for many designs of aircraft, after Pren wire was introduced.

Other wire types were still in use, in the post-war period, but these tended to be for very specific applications and limited in use and not discussed here. Any wire type of this age should now be considered as well beyond its *“replace by date”,* even though all these types can still, occasionally, be found in use.

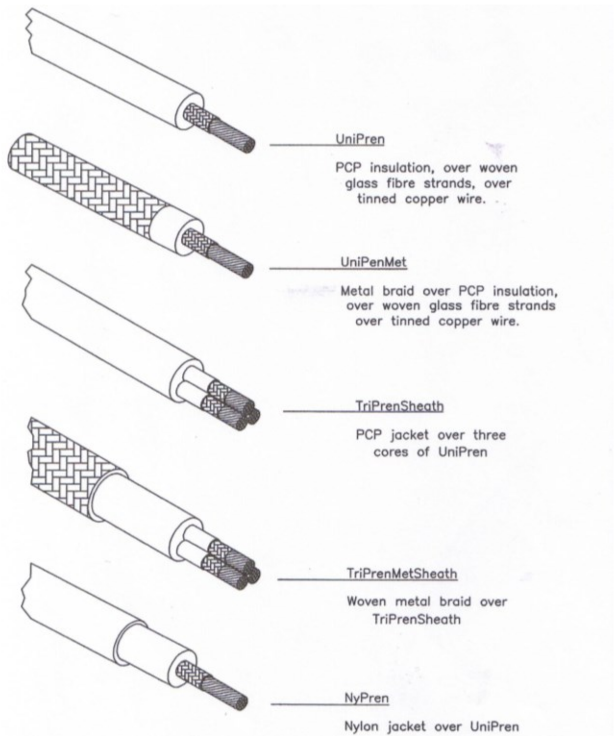
Wire types - Pren wire

During the first decade of the period covered by this report, Pren wire, which was introduced in 1949, became the standard British general purpose airframe wiring material, but is now considered obsolete for aircraft use, other than for direct replacement. This material, which remained in production and use, for industrial applications, well after the period of time being examined, is now largely unobtainable. In many cases, particularly through in-service modification programmes, Pren was directly superseded by Nyvin and Minyvin, which, in turn, have since been superseded by various modern lightweight insulation wires.

Pren wire is manufactured from tinned copper wire, covered in an insulating sheath of woven glass braid and an outer layer of Polychloroprene, *(PCP, also known as Neoprene),* a synthetic rubber material. It is a very flexible wire, but clean stripping of the insulation and glass braid is not easy and often requires trimming, with scissors, to produce a clean edge. The wire uses a colour coding system, in the outer jacket material, up to cable size Pren 12; above this all cables are coloured blue. The wire size number denotes a nominal current rating.

Pren was produced in several forms. *(See Fig. 2).* As a single wire; as a screened wire, with an overlay of tinned copper braiding; as a multi-core cable with an outer jacket of polychloroprene and as a multi-core cable with individual or group screening of wires and an outer jacket of polychloroprene.

Figure 2 - Examples of PREN wire types



In 1953, a variation called Nypren came into use. This was standard single-core Pren wire, with an additional outer jacket of transparent nylon, for smaller wires and a lacquered nylon braid for larger wires. This was for use in areas where there was risk of contamination by the more aggressive synthetic Ester-based lubricants, which were then coming into use. The outer nylon jacket also increased abrasion resistance. Rather confusing, however, is the fact that Pren and Nypren wires have often been found running adjacent to each other, in particularly harsh environments. Nypren is readily identifiable as having a glossy finish, rather than the matt finish of Pren.

The manufacturers of Pren wire; whilst they would not put an exact figure to the life expectancy of the cable in any particular installation; considered that the material had an anticipated life of 25 – 30 years. This, however, has been shown to be dependent on installation position, contamination by fluids, exposure to UV light and to weather, heat, humidity and condensation.

At the time of writing, the oldest aircraft covered by this report may have wiring that is in excess of 70 years of age, although some of the original aircraft wiring harnesses may have been repaired by replacement, during defect rectification, or the harnesses replaced by modification programmes.

It is worth noting that numbers of Hawker Hunter aircraft in RAF and RN service, which had originally been built, during the 1950s, with mainly Pren and Nypren wire, were, during the mid-1970s, the subject of a complete re-wire programme, using Nyvin and Minyvin, to allow them to remain in service, due to deterioration of some areas of the Pren wire.

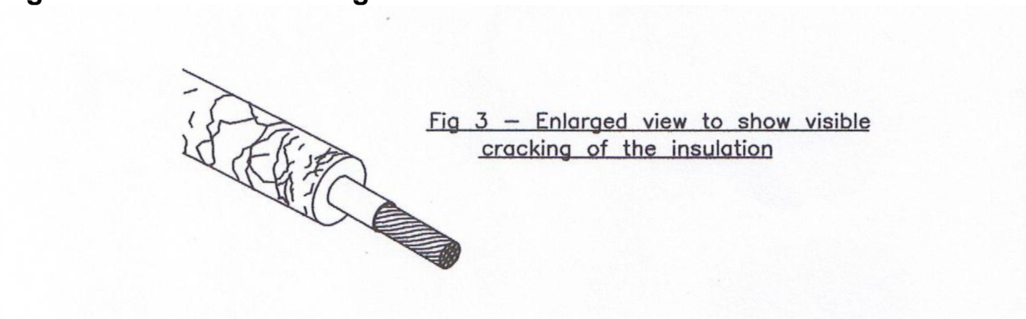
However, for comparison, the Vulcan restoration project saw the retention of over 60% of original Pren wiring fitted to the aircraft, after it was assessed as Serviceable, using defined methods of inspection, developed from the comments in this report. This serves to indicate that the ageing wiring problem is not necessarily a showstopper, but can be dealt with, as part of the approach to ageing aircraft maintenance.

Pren wire – ageing and condition

During planning of aircraft restoration projects, the author discussed the ageing of Pren wire with a manufacturer, Lucas-Rists Wiring Systems (since closed). The ageing process for Pren, is one where the Polychloroprene insulation material will change molecular composition as a result of age and particularly, with exposure to heat and ultra-violet light. This leads initially to hardening of the material and then microscopic cracks appearing in the insulation, which will eventually lead to the cracks growing to a size, where they become visible. *(See Fig. 3).*

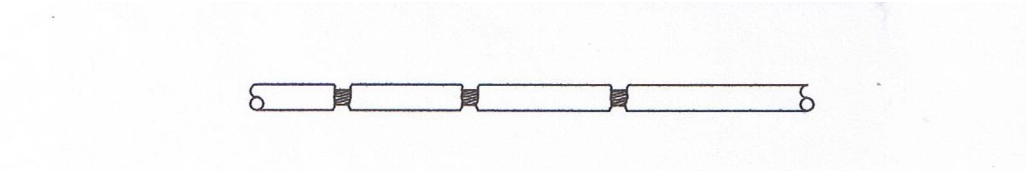
The material becomes friable and with vibration or handling, begins to crumble and collapse. It will then fall away from the inner woven glass braid, leaving this as the only insulation around the tinned copper wires; *(this is commented on later in this report).*

Figure 3 – Visible cracking of the insulation



This loss of insulation is particularly noticeable on single wires, where they break out of larger wiring harnesses, rather than within the harnesses and is probably the result of vibration, as witnessed by node points and lack of good support. (*See Fig.4).* It should be noted that this deterioration does not occur in all cases, as explained later.

Figure 4 – Sketch to show loss of insulation at node points



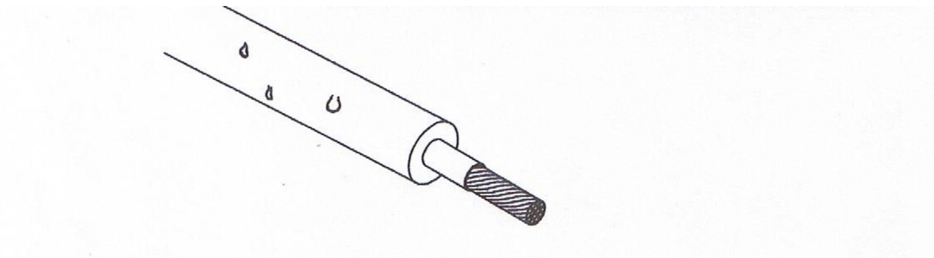
Some heavy-duty wires, *(e.g. Pren 135, where 135 indicates a nominal current rating),* which are used as power feeders, have been seen with longitudinal splits in the outer jacket, on the outside of a bend, where they have a tight bend radius. The jacket of these larger wires has a wrapped finish, rather than extruded.

Where the wires are subject to water/ moisture contamination, the water/moisture can penetrate the early microscopic cracks and lead to voltage tracking between adjacent wires and structure. It may even be that the insulation material becomes semi-absorbent, due to the capillary action of the microscopic cracks. The water/moisture contamination can be caused by direct ingress of rainwater onto cables, through leaks around hatches and panels; or condensation, as a result of temperature cycling, whether by ambient air temperature; pressure and humidity changes or operations, such as engine running and flight. In areas where the Pren wire is open to direct water contamination, (e.g., Undercarriage and Flap bays), the cable outer jacket is often leached of the colour pigmentation and can display as any lighter shade of the original manufactured colour, back to a whitish-grey colour.

The Journal of the Institution of Electrical Engineers *(September 1967)* carries a detailed report on Pren wire. This records that the construction of Pren with glass braid next to the conductors allows 'wicking' of moisture, from termination points, along the length of the wire. It also notes that during development trials, Pren was produced without the glass braid and only the PCP insulation. The insulation resistance of this wire was much lower than the glass braid and PCP wire. It must follow, therefore that the insulation resistance of wet wire must be reduced. This was a particular problem in tropical areas, with high humidity and many military service aircraft manuals make note of this fact, when detailing processes for carrying out insulation testing of cable harnesses.

In cockpit areas, in particular, but also in other areas, it has been noted that the degraded wire often has tear-drop shaped staining on the outer surface, which is brown in colour, regardless of cable jacket colour and has a slight waxy feel to it. *(See Fig.5).* This ***may*** be due to a combination of condensation and ingredients of the cable jacket, which are exuded from the material and is caused by the wide range of ambient temperatures that can be experienced under plastic aircraft canopies.

Figure 5 - Brown 'teardrop' staining of PREN jacket



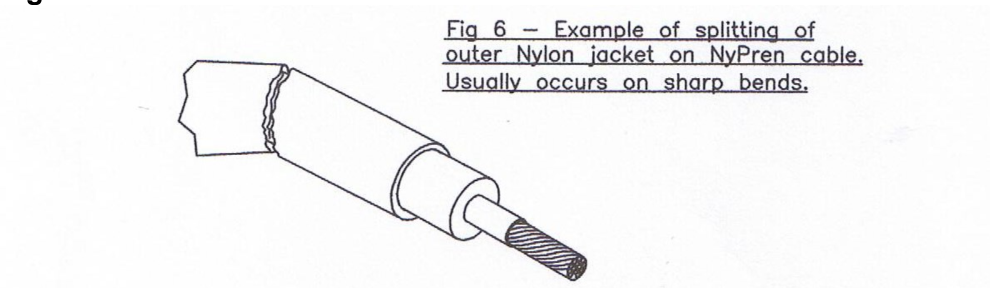
Additionally, in areas where the cables can be contaminated with engine oil, hydraulic fluid or more particularly fuel, the contamination can cause the wiring insulating material to soften and greatly expand and change to a jelly-like consistency. A manufacturer's catalogue for Pren indicates a 20% maximum increase in wire insulation diameter, when contaminated with fuel, although observation has shown examples of much larger expansion, which eventually leads to complete collapse of the insulation.

In some cable harnesses, where Pren wire is sleeved in PVC sleeving, *(a particular feature in the Plessey Wiring System),* the individual wire insulation remains very flexible and still has good insulating performance, in comparison to areas where the wire is not sleeved and shows marked degradation. This could, of course, also be due to replacement of harnesses, post-initial build. *(See also, notes on Sleeving, below).*

Multi-core Pren cables, which have a number of inner cores of Pren wire in an outer jacket of Polychloroprene *(PCP),* often show signs of degradation of the outer PCP jacket, to the extent that it readily splits and breaks away. The inner individual wire insulation does not appear to deteriorate to the same extent.

Nypren wires, with the outer Nylon jacket tend to be in better physical condition, than Pren. However, it tends to suffer from the specific problem of circumferential cracking of the outer Nylon jacket, at tight bend radii, or, where single wires break out from a cable harness, due to vibration, and poor support of the wire. Cracking of the hard nylon jacket can then lead to a physical breakdown of the softer, underlying insulation material, exposing the conductors. *(See Fig. 6).*

Figure 6



When new, the colour of Pren wire is a bright colour, (blue, red, brown or yellow). It has been noted that new material, which has been used for repairs, can change colour fairly rapidly, (six months to a year) and can become increasingly dark with age, even in closed areas of an aircraft. This is possibly due to oxidisation of the insulation and does not directly affect its performance. The effect is less noticeable in sleeved wires; indeed, even seventy-year-old wires may be found to have the original bright colour and are highly flexible, when removed from sleeving.

The commonest problems noted with Pren wire, which has been mentioned above, are as follows:

a). Breakdown of the insulation composition by UV contamination.

b). Deterioration of the insulation by contamination by fluids.

c). Deterioration of the outer jacket on multi-core cables, by ageing.

d). Cracking of the outer nylon jacket on Nypren wires, leading to total failure of the insulation.

There are two other problems, which will be discussed, in more specific terms, later.

e). Breakage of wire strands adjacent to termination points.

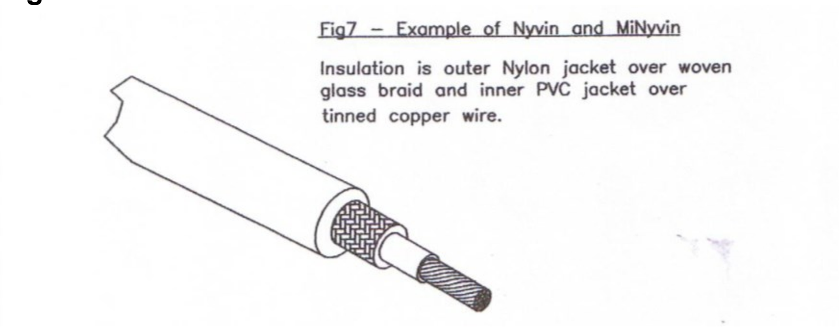
f). Deterioration of spliced repairs or modification to wiring.

Wire types - Nyvin and Minyvin wire

Nyvin was introduced in 1954 and began to appear in British built aircraft, from the late 1950s. Nyvin and Minyvin wire superseded Pren wire as general-purpose airframe wires.

Nyvin consists of tinned copper conductors with an extruded Polyvinyl chloride *(PVC)* jacket, which is overlaid with a woven glass braid and sleeved, in a Nylon jacket. Minyvin, which soon followed Nyvin, was produced by the same method, but with thinner levels of insulation, to reduce diameter and weight and consequently, voltage rating. *(See Fig. 7).* MinNyvin is simply a lower voltage rating version for the same gauge wire, with thinner levels of insulation. The construction is the same as for Nyvin.

Figure 7



Variations, called Nyvinmet and Nyvinmetsheath was also produced, the former had an additional outer layer of tinned copper braid and the latter had braid and a second Nylon layer over the basic wire form, for screening purposes.

Nyvin and Minyvin wire – ageing and condition

Nyvin and Minyvin from this period often appear to be in reasonable physical condition with a visual inspection; (*this comment is based on extensive experience, gained with a particular aircraft type built during the early-mid 1960s and still being regularly worked upon*). Where Nyvin or Minyvin wire is exposed to UV light, however, it can lead to cracking of the outer clear Nylon cover layer. This can eventually lead to total collapse of the outer sleeve and subsequent loss of it and the woven glass braid, (the middle layer), leaving only the inner PVC layer. This is usually only seen in areas with particularly aggressive UV conditions, such as cockpits where it is adjacent to canopies or windows.
Tight bend radii and flexing will also cause cracking of the outer cover layer. Circumferential cracking of the hard nylon outer jacket can then lead to complete collapse of the softer inner insulation and fatigue failure of wire strands. Flexing can also lead to fatigue failure of the conductors, which can, eventually, lead to arcing or overheating within the insulation and consequent damage.

Nyvin and Minyvin wires also suffer from the problem of 'Knuckling', when individual wires have been added to wire harnesses as a result of repairs of modifications. If the wire is pulled through harness securing devices, the 'set' of the wire, *(the curling caused by being wound onto a wire reel during production)* can cause a loop of wire to be pulled tight up against a clip or other wires. This action can cause a 'knuckle' in the wire, leaving the conductors and the insulation severely stressed. If the wire was subsequently straightened out, to remove the knuckle, the inner conductors are often displaced from the spiral wire lay, in which it was produced and lose strength. *(See Figs. 8 & 9).* This has been noted to lead to fracture of the conductors, inside the insulation sleeve. Pren wire, which is much more flexible, did not appear to suffer from this to the same extent.

Figures 8 & 9

Fig 8 – An example of "knuckling"

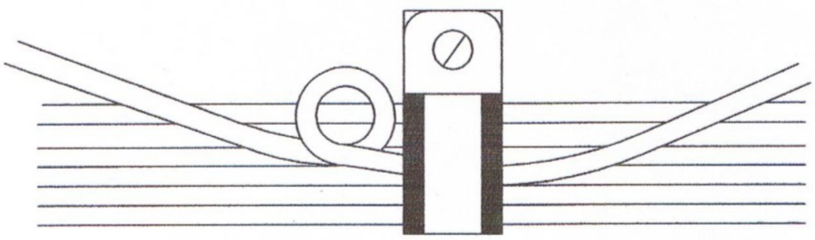


Fig 9 – Example of Nyvin wire, straightened after "knuckling", with the insulation removed, to show displacement of wire strands.

The method of construction of Nyvin and Minyvin will allow oil or hydraulic fluid contamination to penetrate into the woven glass fibre layer and spread over short lengths of the cable, leading to staining and degradation of the inner PVC insulation. A similar condition is often seen with Nyvinmetsheath, where oil or hydraulic fluid can spread by capillary action over long lengths of the cable, within the outer braid. In neither situation of this contamination have instances of failure of the insulation been observed, although most aircraft manuals call for such contaminated wiring to be replaced.

The commonest problems noted with Nyvin and Minyvin are as follows:

a). Localised fretting and chafing, due to poor harness support.

b). Cracking of the outer jacket, particularly on single breakout wires, or on harnesses with only a few wires, or where looms are flexed as a connector needs to be connected or disconnected, leading to damage to the inner insulation.

c). Deterioration of the outer jacket in exposed areas, notably in cockpits, particularly forward of instrument panels, which are exposed to UV light, or undercarriage bays, where it is subject to reflected light and moisture contamination.

d). Poor quality termination work for splicing repairs or modification to wiring.
(The latter problem is discussed later).

Wire types - Other wire types

There were other special-purpose wires, in use during the period covered by this report, which included the following types:

Sub-miniature, multi-core cable, with overall insulation sleeving, for low current applications, such as instrument supplies.

Glasef, Efglas, Glasil and **Tersil,** which were all used in high temperature applications.

Equipment Wire, which was normally used for the internal wiring of radio or instrument equipment junction boxes, but was also used for interconnecting wire harnesses, where the wire was sleeved in a proprietary convoluted PVC or PTFE sleeving, known as Superflexit Conflex sleeving, which is brown in colour.

These types of wire tend to be less frequently used in any given aircraft than Pren, Nypren, Nyvin or Minyvin. Although the Sub-miniature and some types of Equipment wire are PVC insulated; none tend to show the degree of breakdown seen in Pren, though hardening of the insulation and outer cover jacket on multi-core cables, as noted earlier, with Vin wire, has been observed.

Glasef, Efglas and Glasil wires tend to be used in very small amounts in high temperature areas, such as engine bays and whilst few problems have been encountered, other than direct chafing problems, Airwire has little experience in needing to replace these products.

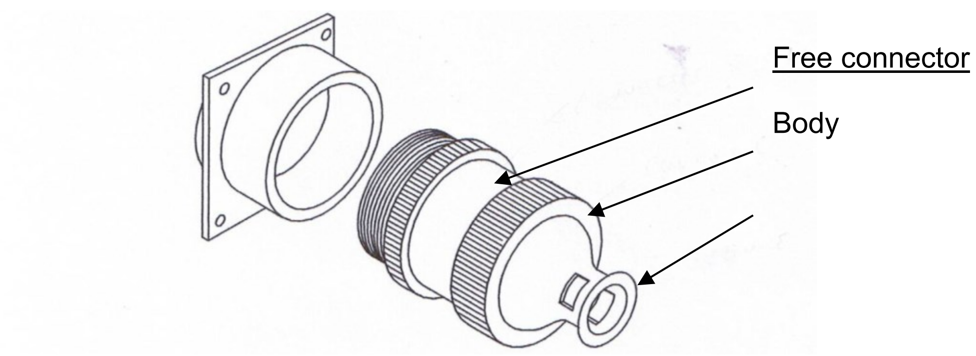
Tersil wires can suffer from abrasion and oil contamination of the outer jacket due to their use in engine bays, but, nevertheless, have excellent resistance to breakdown through the outer sleeving and the silicone rubber inner insulation, but can suffer in areas of direct and long-term fretting against metal edges.

Additionally, different types of Radio Frequency wire were in use and whilst these tend to be generally in good physical condition, some RF wires appear to use a natural composition material in the outer jacket, which can lead to mould growth along the wire insulation, where exposed to moisture/condensation.

Connectors

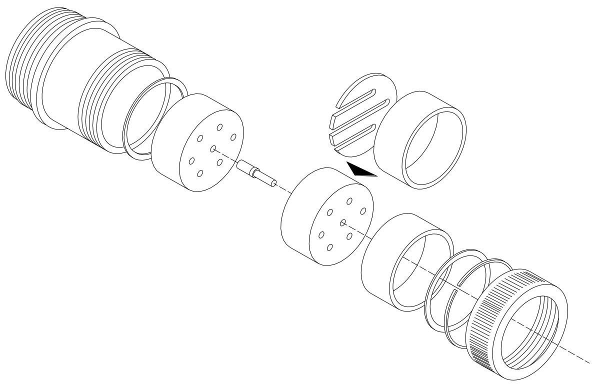
During the 1950s, multi-pin circular connectors came into wider use on British-built aircraft. The majority of these connectors were Plessey Standard connectors, but the Plessey Mk 4, Mk 5 or Mk 7, were also used, for connection to equipment boxes. The Plessey Standard connectors were also known as Ex-Breeze, *(or more commonly, Breeze),* as they were directly developed from a wartime American wiring system, known as the Breeze Wiring System. *(See Fig. 10).*

Figure 10 – Example of Plessey Standard free and bulkhead connectors



The Plessey Standard connectors went through several stages of evolution, during the period in which they were specified for aircraft designs. The stages included different methods of assembly of the internal contacts and insulators, as well as several changes to the design of contacts. In Fig 10, the wire outlet is shown as a ferrule, to which wires could be secured. There were a number of other styles of fittings, which included angled outlets and a double ferrule, to clamp PVC sleeving into position. Fig 11 shows the internal layout.

Figure 11 – Plessey Standard Free Connector – Internals

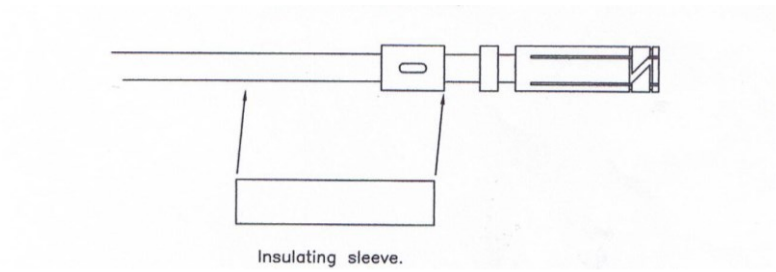


The internal contacts and insulators were specific to particular standards of evolution and should not be mixed. Two styles of layout are shown, but there were six differing styles.

The early style of Plessey Standard circular connector were designed for crimp contacts, although they are sometimes found with soldered contacts, which appear to be part of the original manufacture. The connector shells could be of aluminium, brass or steel depending on the application. This has, on occasions, led to different material connectors being fitted, when one has, presumably, been replaced, leading to corrosion problems, due to galvanic action between the differing materials. This can lead to the destruction of the connectors, during removal, even with the use of penetrating lubricants being used to assist release. *(See comments on thread lubrication, below).*

The Plessey Standard connector removable pin and socket inserts, whether soldered or crimped, do not provide direct support for the wire insulation, where the wire is attached to the contact. Stretchable neoprene or PVC sleeves were used to support the wire to insert joint and to act as an insulator and sometimes as identification sleeves *(See also section on Wire support, insulation and Identification). (See Fig. 12).*

Figure 12 – Plessey Standard crimp socket, late version



In the illustration, above, the contacts are formed from machined solid pieces. In earlier versions the contacts were formed from rolled sheet, which were subsequently declared obsolete. The shape of the contact varied across different evolutions of the connectors and they are not interchangeable. The neoprene or PVC sleeves are frequently found to be in poor condition, though this is mainly in high temperature areas.

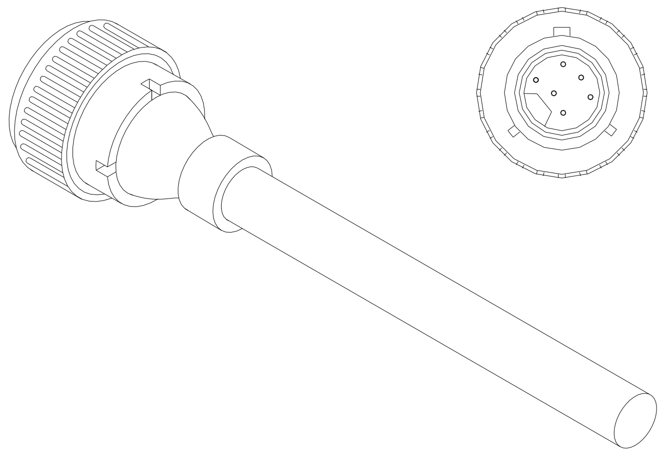
A requirement specified by the manufacturer, when using the Plessey Standard and other types of connectors, was that the threaded coupling sections should always be cleaned and smeared with a light coating of silicone grease, prior to mating. Lack of this precaution can lead to damage particularly on aluminium and brass connectors, causing stripping or cross threading of the screw threads,

The method of release of these connectors requires that the Coupling Nut, *(See Fig. 10),* which locks the connector body parts together, must be loosened, **before** any attempt to release the free connector from it's mating fixed connector. Failure to do this will prevent the inner parts, contacts and insulators, moving freely relative to the connector shell, as it is unscrewed and causes damage to the mating contacts and wires. A common problem experienced with these connectors is the inability to unscrew the free cable connector from the bulkhead connector, due to corrosion on the interlocking threads. This usually requires the liberal use of penetrating lubricants and as given above, ensuring that the contacts and insulators are free to move, relative to the connector body, before attempting to remove the connector.

A useful reference is Air Publication 113D-1825-1, Plessey Standard (Ex--Breeze) connectors. For the earlier Breeze system refer to AP 1095A, Volume 1, Section 3, Chapter 5.

The Plessey Mk 4, Mk 5 and Mk 7 connectors were primarily used with Sub-miniature multi-core cable, which had PVC insulation or with individual PVC or PTFE insulated Equipment wires, which were then contained in a special flexible conduit, known as Superflexit Conflex or standard PVC sleeving. These conduits could also be fitted to Plessey Standard connectors and other types of connector, mentioned below, using a range of adapters and are often found to be in good condition. At a later stage Nyvin and Minyvin was also used with these connectors.

Fig 13 - Plessey Mk 4



Plessey Mk 4 connectors which are of aluminium construction *(see Fig 12)* and Mk 5 and Mk 7 connectors, which could be of brass or aluminium, depending on application, used soldered contacts and were mainly used as radio, instrument and electrical equipment connectors. The Mk 5 and Mk 7 connectors are similar in appearance but had a bayonet type locking device, rather than a screw thread. Refer to AP 113D-1824-1 (1st Edition), Plugs and Sockets, Plessey, Mk 4 and 5 and 2nd Edition for Mk 7. Refer to AP 4343C, Volume 1, Book 3, Section 5, Chapter 22 for Superflexit Conflex.

During the later 1950s, other styles of circular connector appeared in British-built aircraft, namely Hellermann HAN and Plessey UK-AN series of connectors. As indicated by the description, these were based on the American AN specification series of circular connectors. These types were not used, as far as can be determined, with Pren wire, but usually with Nyvin wire, or Equipment Wire, where the flexible conduit or PVC sleeving could again be used, using appropriate adaptors.

Both of these styles of British connector, made use of the connector's shaped, resilient rubber insulation material to hold and lock the wiring contacts in place and support the wire to contact joint. In some cases, packing sleeves were fitted, to tighten the grip on thin wires, where necessary. They are both similar in external appearance to the Plessey Standard connectors. Both types require special tools and lubricants for the insertion and extraction of contacts.

As the resilient rubber inserts have hardened with age, removal and insertion of contacts can be very difficult and can lead to damage to the rubber insert.

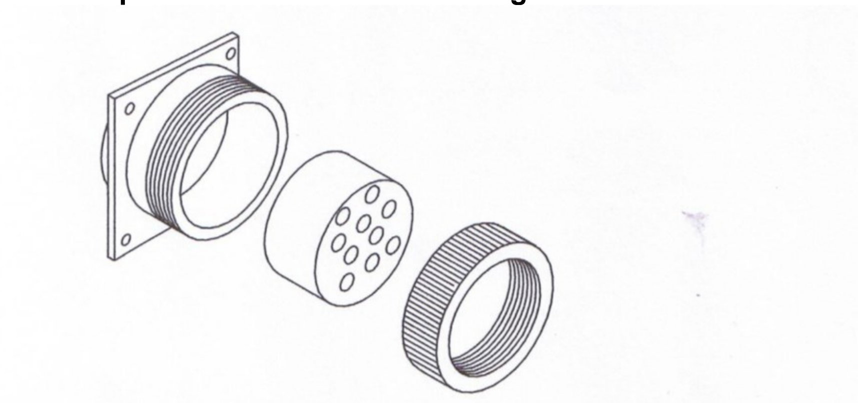
Circular connectors, produced to the earliest American *(AN or MS)* specifications also began to appear in British aircraft designs. These styles subsequently became the universal norm, for aircraft use, eventually leading to the wide range of modern high-density contact versions, in use today.

Rectangular connectors, used with avionics equipment racks, where units were slid into position and then locked, also began to appear in use. The method of fitting units into the racks reduced the loading stress on the connectors and they would give long service, without problems. At the age of wiring systems, that are being discussed, however, the wire terminations, at the rear of the connectors, will be suffering general ageing problems, as discussed, later.

Cable bungs

The Plessey Standard connector types, mentioned above, had special bulkhead styles, to allow cables to run from pressurised areas of the aircraft to unpressurised areas. An additional method of achieving this was by the use of Hellermann Pressure Bungs. These were PVC sealing bungs with wires passing through holes in the bung, which could be clamped to compress the PVC and create an effective pressure seal. (*See Fig. 14).*

Figure 14 Example of Hellermann cable bung



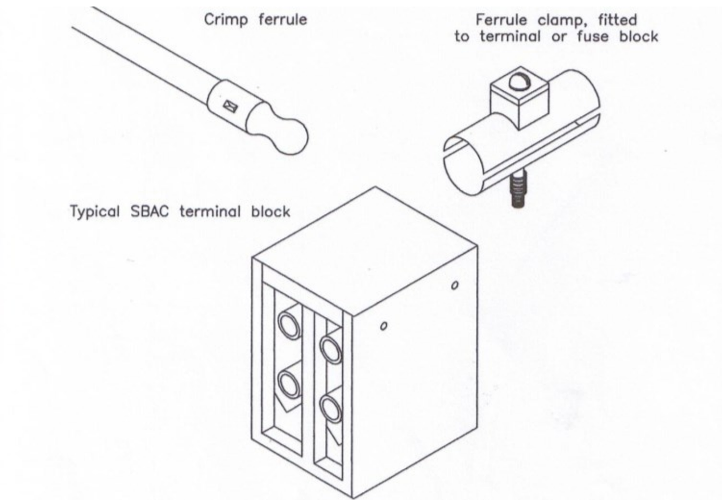
Due to the age of material, which is being discussed, natural bonding between the materials may produce a seal, which will often cause damage to wiring insulation, when attempting to separate them.

Terminations at terminal blocks, fuseholders, switches and circuit breakers

The SBAC Standard Wiring System used crimped ferrules, to terminate wires. These were fitted at terminal and fuse blocks, using a two-part shell clamp to secure them.

A 2-way unit is shown, at Fig 15, but they were also produced as 3, 5 and 15-way, with 2 and 3-way for a heavier duty version. Links can be added to connect terminals together, expansion.

Figure 15 - examples of SBAC Wiring System components



An important feature of this type of terminal attachment is that the crimp terminal body must be raised, by lifting the wire **and** the terminal, after the locking screw is slackened sufficiently, to release the ferrule from the ferrule clamp. Failure to do this correctly, results in stress on the wire to terminal joint and damage the upper half of the ferrule clamp. The damage will cause cracking of the upper part of the cable clamp, leading to a reduction in the contact surface area and therefore potential over-heating and eventual failure.

Although the crimped terminal provided a degree of insulation support, this was not very satisfactory and the ferrules required sleeving for both wire support and insulation.

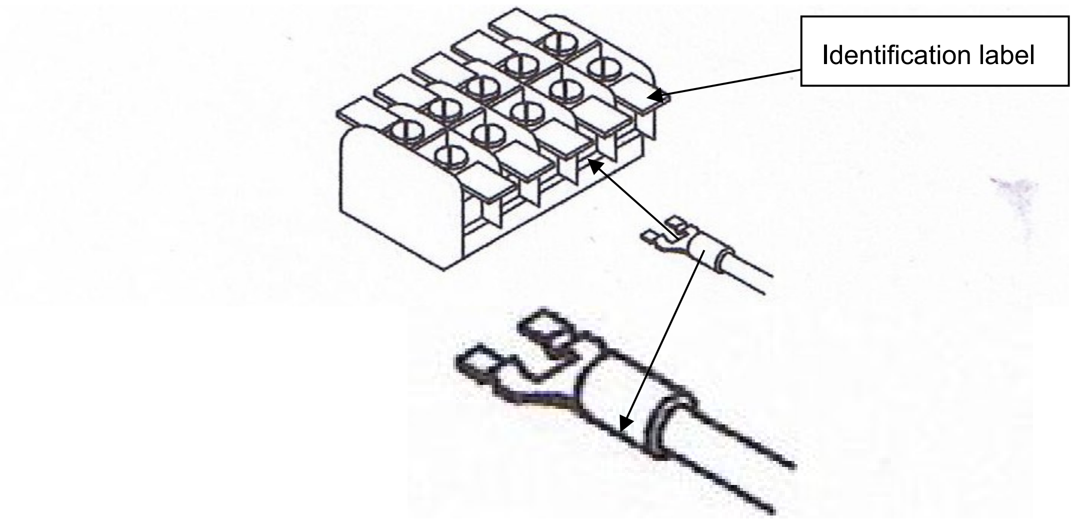
The clamps are often found with heavy oxidisation on the exposed outer surfaces, but the mating surfaces of the terminal and clamp can still be bright metal. The clamps can be removed from the terminal block body, by unscrewing and are readily cleaned with metal polish. Unused contact positions should always have an unwired terminal fitted, to allow the correct clamping action of the screw.

Mention was made earlier of overheating causing distortion of SBAC terminal blocks and fuseblocks. This led to expansion bending of the base of the unit, on longer units, which caused the end plates to deflect outwards, which then caused the top cover, which was secured by spring loaded catches to become loose. On military aircraft, an STI (Special Technical Instruction) was issued to secure the top cover with adhesive PVC tape. In many cases this proved satisfactory, but in oil contaminated areas, the adhesive could be softened, so that the covers again became loose.

Terminations at switch and circuit breaker equipment were usually onto screwed terminal blocks, where soldered or crimped ring tags were used, also with sleeving.

The Plessey Wiring System used crimped, quick release, forked terminations at terminals and fuse blocks. *(See Fig.16).* The forks have opposed indentations, to assist location. Each terminal has a cranked flag, which carries an identification label and has a spring under the screw head, to apply pressure. To install or remove a terminal, the screw must be sufficiently slackened, to allow the terminal to be lifted and moved clear of the locating indentations.

Figure 16 - Typical Plessey Quick-release Terminal block and terminal



Plessey claimed that, even if the screw was not fully tightened, the spring would apply pressure to allow electrical contact to be maintained. The terminals were designed to accept two contacts, fitted so that the contact wire barrels were back-to back, but are occasionally seen with three or even four contacts, where wires have been introduced by modifications.

This practice, whilst having been officially sanctioned, will cause distortion and strain to the terminals.

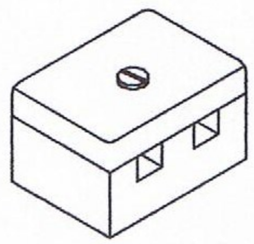
There are a number of variations of crimp terminal in use, with the Plessey terminal blocks. The original Plessey terminal comprised of two parts; the terminal contact and an outer ferrule, which was placed over the wire end and the whole crimped into position. This was later replaced by a one part crimped terminal, produced by Hellermann. Finally there was a PIDG (Pre-insulated Diamond grip) version, produced by AMP (Now Tyco). In each case, the appropriate crimping tool had to be used.

Regardless of the type of contact in use, locating terminals into the fuse or terminal blocks can be difficult, particularly in poor access areas, where they are not clearly visible. The spring pressure can make it feel or appear that the terminal is fully located, when it is not. Tightening the screw, in this case, will clamp the terminal, but it will not be fully located and can subsequently become loose, or cause overheating. Terminals should always be inspected, using a light and mirror, if necessary, to ensure that the terminals are fully home.

Aircraft, using either, or both the SBAC and the Plessey Wiring systems, also made occasional use of the much earlier AM *(Air Ministry)* screw connection terminal blocks, which were originally designed for two-pole *(non-fuselage earth return)* systems. *(See Fig.15).* These could have the bare wire clamped under screw head and washer, or sometimes, used a circular soldered or crimped tag.

There were a number of differing sizes, for higher current applications, as well as 2, 3 or 5 terminal variations. *(See Fig. 17)*

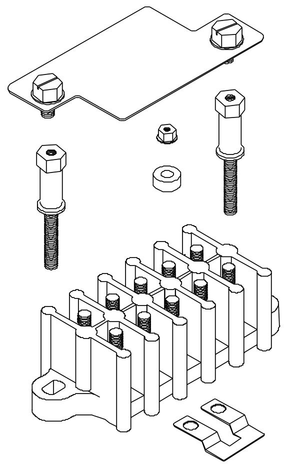
Figure 17 - Typical Air Ministry terminal block (2 way)



These types of terminal blocks, which have cable entry channels from both sides, are often seen with modern PIDG terminals attached, which is satisfactory, if only one wire is routed into each cable channel. If more than one terminal is co-located, from the same side, the size and shape of the cable barrel will distort the terminals. A variation of the early Hellermann crimped ring tag terminal was designed to overcome this problem. It had a longer contact shank to allow two wires to be co-located, back to back and clear the terminal block body. These items are still occasionally available from ex-military equipment stockists. This problem may also be overcome by terminating two wires into the same crimped terminal, where suitable, as indicated in many terminal manufacturers' catalogues.
Mention was made earlier of Ward Brooke terminal blocks, which came into use in the 1950s. These consist of terminal studs mounted between insulating walls and moulded into a single unit, (see fig 18). They range from 1 to 20 terminals and could be single or double row, with some used as bulkhead penetration, with terminal studs to both sides. Each

terminal, on a single row, is capable of having up to eight wires attached, with the use of a spacer and this can be further increased by the use of inter-terminal links. The terminal blocks are provided with fixing posts, which is designed carry an insulating top cover. They are available in a range of colours, to indicate the application.

Fig 18 – Ward Brooke terminal block (5 way, double sided)



These terminal blocks are still produced by Ultra Electronics. A useful reference is AP 113D-1903-1, Ward Brooke terminal blocks.

Special torque-loading spanners are used with Ward-Brooke terminal blocks. These have pre-set torque values, specific to the contact and nut size. They are available from Soltork Products Ltd.

Problems at terminal blocks, etc

The soldered, crimped or screw clamped terminals, attaching wires to terminal blocks, switches or circuit breakers can be an area of concern. Poor quality, or aged soldering and loss of insulation sleeves can lead to problems similar to those detailed in the next section. Additionally, localised formation of copper oxide often leads to severe corrosion of the terminals. A reference in the Journal of the Institution of Electrical Engineers notes that this problem was encountered during the 1950s and was due to the fact that, initially, no standardisation was, at the time, laid down for the thickness of tin plating to be applied. This could lead to erosion of the tin plate on the contacts, leaving the copper body exposed and leading to copper oxide corrosion forming on the terminal and wire and eventually, to possible mechanical failure. With the age of materials now being considered the tin plating may well have depleted, due to natural erosion.

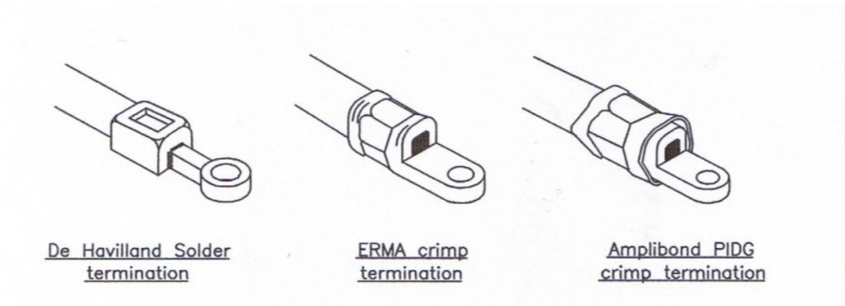
A further problem with existing soldered joints is that when attempting to re-solder the wire, the depletion of the tin plate on the wire or contact and oxidisation will often make re-soldering of aged wire very difficult.
Insecurely tightened screws or nuts securing terminations to terminal points can lead to localised over-heating of the terminals, such as where wires are attached to terminal blocks, circuit breakers, switches and bus-bars.
Screws or bolts, used for the mounting of terminal blocks, switches and circuit breakers, to the airframe, are frequently found to be corroded, even where they were the specified plated screws. A reference in Aircraft Engineering magazine *(1956)* attributes this to voltage

tracking in damp conditions, destroying any kind of plating.
American terminal blocks of a similar vintage are single row studs, without the insulating wall between the terminals, have simple pillars which sit between studs to prevent wires/terminals being pulled against the adjacent terminal. A push-on plastic cover provides for insulation

Heavy duty cable termination

The comments, so far, have been orientated at smaller gauge wires, up to say 10 awg. Larger gauge wires, such as battery, generator and starter cables, also need to be considered. In the early period covered by this report, heavy-duty terminals are often soldered connections, even though crimped heavy-duty connectors for both wiring systems were available, at the time. This has been particularly noticeable on Vampires and Venoms, built as late as 1959, where special De Havilland solder contacts were used. *(See Fig. 19).* The larger size of wire and therefore termination, generally mean that they are more robust and less likely to be damaged than smaller gauge wires. The comments about insulation sleeves and corrosion, given below, however, still hold true.

Figure 19 - Examples of heavy-duty terminals



Other, later, variations of these terminations were likely to be crimped, using ERMA crimp tags, or later still, AMP Amplibond *(Pre-insulated)* types. There was, at the time, no military in-service tooling available for the Amplibond terminals, so these, therefore, had to be replaced with ERMA or AMP Solistrand heavy-duty crimps, for which specific tooling was available, when repairs or modifications were carried out. Modern terminals, which are to be used as replacements, should only be crimped with the specified crimping tool, unless terminal pull-off test can show that satisfactory crimping action has taken place, when using other styles of tools.

Terminal corrosion

Corrosion may be found on terminals and attaching hardware, but when the attaching screws or nuts are removed, the joint, which should be gas-tight, to be effective, will still have bright shiny surfaces, meaning that the joint was still capable of conducting correctly. If this is the case, it may be possible to remove the surface corrosion, by the use of stiff bristle nylon brushes, provided that the external plating has not been damaged.

Earth points

Prior to the introduction of metal skinned aircraft, any electrical system required a two wire layout, i.e. positive wire to supply a load and a negative line to return the circuit to the power source. With metal skinned aircraft, the designers made use of the metal structure to provide the negative return path, which halved the amount of wire required.

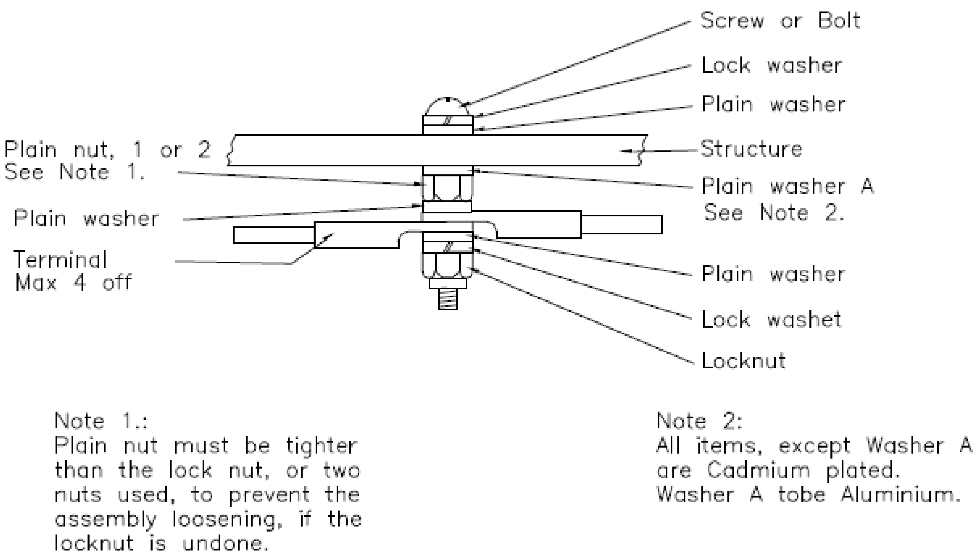
The negative side of the supply is normally described as earth and will tie the battery and generator supply to a fixed point on the airframe, to bring them to the same electrical potential. This would be considered as the Master earth. Other earthing points are provided, around the airframe to allow circuits to be earthed adjacent to the items of electrical equipment. There will be a small electrical resistance value between the Master earth and any other Earth point, but these are considered to be minimal and not effect operation.

The earth points can take a number of forms. Some are metal terminal blocks, attached directly to the airframe, which provide a number of studs to terminate a number of circuits. Others may be no more than a bolt and nut to provide a single or multiple circuit earthing point. Whichever system is used, they are prone to problems. Initially these Earthing points would have been unprotected, but by the 1950s, they were required to be protected with a paint finish. This was to prevent corrosion and oxidisation. Disturbance of these points for the addition of wires, introduced by modifications, often meant that any protective finish was not re-instated. Dependant on the number of circuits attached to any single point, this had a bearing on the amount of heat generated by the multiple circuit currents, at the earthing point. This could eventually lead to break-down of the Earthing point.

If the single earthing point nut and bolt are not assembled in the correct manner, it can result in incorrect torque loading of the Earthing point. This can lead to a less than gas-tight joint, leading to an increase in circuit resistance and the therefore the heating effect.

The correct method of assembly, for a single Earth bolt is shown in Fig. 20, below. Note that this is for a stud-type earth bolt on an aluminium structure, with tinned copper terminals. Where an earth terminal is attached to other materials, Washer A must be of the same material.

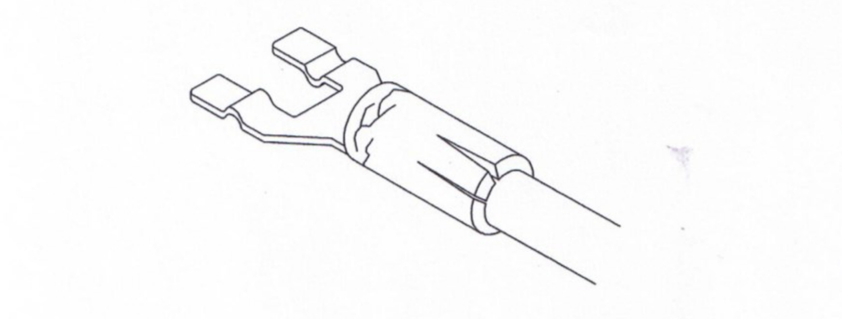
Figure 20 - Stud-type Earth bolt



Wire support, insulation and identification sleeves

Wire support, insulation and identification sleeves for Plessey Standard pin and socket contacts and other contacts and terminals were usually either of PVC, known as Helvin or of synthetic rubber, known as Helsyn 100 or 150, sleeving, *(the number referring to temperature rating)* and all produced by the Hellermann Company. *(See Fig. 21).* In aircraft types, which are the subject of this report, both the PVC or rubber sleeves can become hard or perished, leading to cracking and splitting of the sleeves, so that the sleeve can fall away from the wire. This can, through vibration, lead to mechanical failure of the wire strands.

Figure 21 - Example of support/insulation sleeves with cracking and splitting



In areas of fluid contamination, the sleeves can swell, as noted earlier, with Pren insulation and similarly leads to disintegration of the sleeve. This, in turn, leads to loss of support of the wire, which can then lead to breakage of individual strands and over-heating because of the reduction in current-carrying capacity at the termination points, which are the weakest areas anyway.

The same materials were also used for overall identification sleeves for wire harnesses, with hand written or printed identification information.

PVC Sleeving

The black protective PVC over-sleeving used on many wire harnesses, but as a specific feature of the Plessey Wiring system, was, when fitted, soft and flexible. However, in some areas it can become hardened and brittle, either through age, exposure to heat (e.g. Engine bays), UV light or a combination of all.

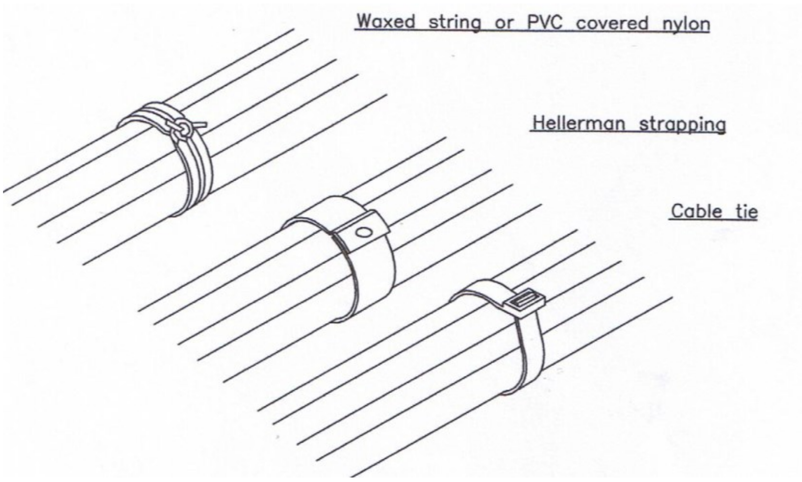
This degradation can transfer vibration onto individual wires, in a cable harness, increasing the risk of mechanical failure of those wires. It also creates a potential loose article hazard, when the sleeving breaks apart, as can often happen. When the sleeving fails, it will usually crack along the length of the sleeving tube and at any acute bend points, where the sleeving may have creased and is under stress.

This could lead to broken pieces of the hardened sleeving falling into areas, where there could be potential for jamming of engine or flight controls.

Cable and harness support

Various types of wire harness securing and support devices are used throughout the service period of these aircraft. These included tying with waxed string or PVC covered nylon cord; two styles of Hellermann Stud and Strapping (PVC or Nylon); Nylon cable ties of various manufacture, as well as cable clips, (P clips). *(See Fig.22).*

Figure 22 - Examples of cable support



Of these, experience has shown that the Nylon stud and strapping and Nylon cable ties, *(which began to appear in the late 1960s*) are more prone to failure, by age, UV exposure or heat hardening, resulting in cracking, than the other, earlier, systems. However, reference, to a Panduit catalogue, *(a supplier of cable ties),* shows that unless they are weather resistant, by the inclusion of carbon black, cable ties have poor UV resistance. Most ties seen in older applications are white/natural. Black cable ties are therefore recommended as replacements.

The earlier, *(PVC),* version of Hellermann stud and strapping, however, often remains soft and flexible and fully reusable, when compared to the later *(Nylon)* type and is still available commercially.

The waxed string or PVC covered nylon cord can locally distort the wire jacket leading to the failure of Pren insulation, as described above. The knots in PVC covered nylon cord can sometimes loosen and the cord fall away from the cable harness.

Cable clips

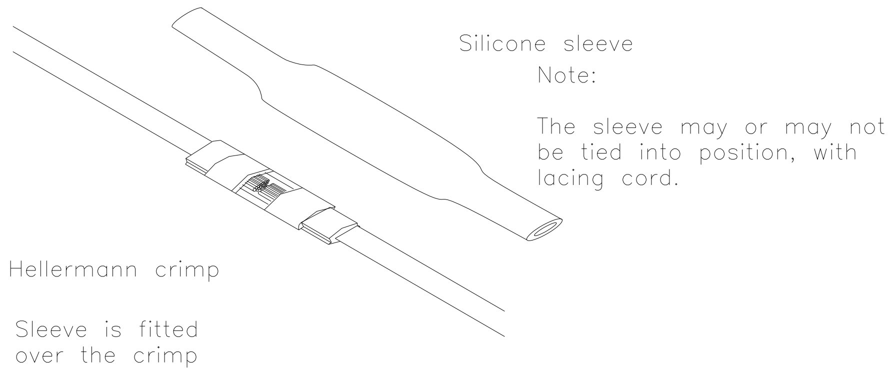
Cable clips, often described as P clips, which are used to support cable runs, are usually a rubber-covered metal clip. The British makes of clips, of the period, included aluminiun clips covered with a thin PCP rubber *(the same material as Pren wire insulation)* cushioning sleeve, of the AS 3180 type, as part of the SBAC Standard Wiring System. In many cases the PCP rubber is perished, or split, or has disappeared, leaving the metal clip loosely supporting the wires, with the probability of chafing or cutting. Other, more durable, nitrile or silicone rubber padded cable clips, of various specifications, usually of steel, whose initial design was for pipe support, were also used for cable support. Both types can, however, display cracking of the rubber on the outer circumference of the clip cushion and the possible consequential loss of the cushioning material.

Solid nylon cable clips are also seen, where the clip material has hardened and then cracked. This usually happens at the sharp radius bend of the uppermost clip attaching lug and can be difficult to identify, with the clip in situ. The cracking can also occur anywhere around the radius of the clip. This, again, happens more frequently with white/natural, rather than black clips.

In-Line splices

The use of soldered in-line splices, for the temporary repair of damaged wires or introduction of new sections of wire, by modification, began during World War II, having been specifically banned prior to this time, with simple twisting together of bared conductors, soldering, tape wrapping and tying to adjacent wiring. Later crimped metal splices were introduced. These were, initially, simply a tinned copper tube, which was soldered or crimped to the wire and then protected by sleeving. As with other wire terminations, this gave no support to the wire to termination junction and Hellermann In-line crimp splices were then introduced, which crimped both the wire conductors and insulation. They were an all metal splice and were sleeved in a contoured silicone rubber sleeve, which was tied into position, to provide an insulating and environmental cover. *(See Fig. 23).*

Fig 23 - Hellermann in-line crimps



These types of Hellermann splice are now often seen with the insulation sleeve colour having turned dark brown or black, (from the original bright red colour) and with heavy oxidisation of the metal crimp. Examination of samples of this type, have shown that the crimp joint can suffer in the same manner as crimp terminals, discussed above, when not well supported. However, the spliced joint had to be secured within an existing wiring harness and not, therefore, usually subject to the vibrations that single terminated wires might suffer. Although often heavily oxidised, the mechanical strength usually remain good, though with increased age, corrosion will eventually lead to increased resistance, over-heating and a consequent voltage drop.

From about 1965, AMP PIDG (Pre-Insulated Diamond Grip) type in-line splices began to supersede the Hellermann splices and although these were insulated, using an overall nylon sleeve, they were not of a sealed type. AMP terminals are now marketed as Tyco Electronics products.

The use of these splices was very precisely controlled, by Service regulations, as to location and numbers in any wire harness and is similar to CAA requirements, *(which are not actually published by the CAA, but are cross-referenced to a British Standard).* They could be utilised where urgent repairs were required to wiring, to meet operational requirements, but their use was to be recorded and the repaired wire replaced, in due course, unless their permanent use had been approved by an Engineering Authority. The use of in-line splices was also allowable for permanent installation, where specifically called up by the Design Authority, but had to be shown on circuit diagrams.
The reality is that such repairs are frequently found unrecorded and in areas that were not allowable in the regulations. The standard of the repairs is often not satisfactory, in terms of support, identification and location.

Examples of such problems, which have been frequently encountered, are:

a). Lack of adequate wiring support to either side of the splice.

b). Lack of circuit identification, on both sides of the splice, for wiring which does not have printed code markings, along its length.

c). Use of splices in engine bays, earthing braid leads, flexing cables and other circuits, where they are specifically banned. This is often noted in areas where a cable harness will pass into an engine bay from a wing or the fuselage and new lengths of wire are simply added by splicing, because of the difficulty in working aft of a firewall, which can be a confined area.

d). Installation of multiple splices in the same length wire or in adjacent wires, without adequate separation.

e). Breakdown of the splice by corrosion and over-heating.

The British Standard Institute's BS 2G 180 specifies the limitations on the use of wiring splices.

By the 1980s, when some of the aircraft types, which are the subject of this report, were still in Service, the RAF regulations required replacement of deteriorating Hellermann splices and sleeves. This was to be done with a crimped tinned copper sleeve protected by an adhesive lined heat-shrink sleeve, to provide complete sealing of any spliced joint. This requirement eventually led to the introduction of two part splices *(Metal barrel and specific heatshrink sleeves),* an example of which is the Raychem Mini-Seal splice, which are colour-coded to wire size and available for up to 10 awg wire.

Prior to introduction of the Mini-seal splice and for larger size wire, up to 6 awg, a similar result could be obtained by the use of uninsulated AMP Solistrand in-line crimps, over sleeved with a suitable adhesive-lined heatshrink sleeve. The British Standard, however, prohibits the use in wires above 10 awg.

Empire Tape and Systaflex sleeving

From the earliest days of aviation, in design and application, some wire harnesses were spirally wrapped along portions of the harness length, in "Empire Tape", for anti-chafe protection. The tape could also be wound circumferentially around a point on a wire or cable harness, to allow tying of the cable harness, without crushing the insulation, or for the fitment of metal clips, without rubber cushioning. The tape, which is woven cotton or cambric based, with a shellac varnish finish, giving it a yellow finish, often shows signs of ageing, resulting in very weak tear strength, though it may still provide reasonable abrasion resistance. The tape can also become contaminated, in areas subject to oil, fuel and hydraulic fluid leakage, e.g. engine bay and lower areas of the aircraft, resulting in very weak material. This material was still in aircraft manufacturing use, until the late 1950s.

Systaflex sleeving is a similar material to Empire tape, but made in tubular form, with a thicker wall and is fitted over wire harnesses for anti-chafe protection. It suffers similarly from ageing and contamination.

Mechanical damage to wires

During initial installation or once installed, any wire type can be susceptible to mechanical damage by abrasion, fretting or cutting by adjacent structure. Similar damage can occur, where wires are not correctly supported, or by mishandling during subsequent maintenance or modification of an aircraft. Damage problems could be due to poor engineering techniques or routing of cables. These include:

a). Insufficient wire harness support, allowing wires to chafe against adjacent wires of greater hardness, or structure or fixing hardware.

b). Lack of sufficient securing devices to prevent movement

c). Shortening of cable lengths, during repairs or modifications, leading to tight routing into potentially hazardous situations.

d). Hanging lights and other equipment from cable harnesses, during maintenance activities, or even using wire harnesses for a handhold or treading on them.

e). Poor quality control of wire termination practices.

f). Routing wires adjacent to pop rivets, where the sheared mandrels can create a sharp cutting edge, although these should have been rectified during installation.

g). Not clearing metal swarf from drilling or cutting operations, which can then drop, or migrate into wire harnesses. The edges of the swarf can be as sharp as a razor blade.

h). Routing flexing cables over a hinge point, without sufficient length to clear the moving parts at their extremes of movement, or not placing a rotational twist into the flexing portion length, to absorb stress.

The design of most wire types allows for a degree of "pull through ability", to accept some very minor mechanical damage to insulation outer surfaces during installation and service. The definition of what is acceptable is not precisely defined either by the manufacturers of either the cable or the aircraft or by RAF/Navy/Army engineering documentation and is therefore a rather subjective matter for the technicians and engineers involved in carrying out assessments.

However, the standard RAF/RN/Army "Glossary of Terms", given in all British military aircraft servicing documentation, uses the term 'Examine', when defining areas of aircraft wiring (and other systems) to be surveyed. The glossary then defines 'Examine' as:

> ***Examine*** *Carry out a survey of the condition of an item. For example, the condition of an item can be impaired by one or more of the following:*
>
> *Insecurity of attachment*
> *Cracks or fractures*
> *Delamination*
> *Corrosion, contamination or deterioration*
> *Distortion*
> *Loose or missing rivets*
> *Chafing, fraying, scoring, wear*
> *Faulty or broken locking devices*
> *Loose clips or packing on, obstruction of or leaks from pipelines*
> *External damage*
> *Overheating or leaking of fluids, possibly indicated by discolouration*

Minor variations to this list have been noted, in different Aircraft Publications. However, it will be seen that this list of topics co-responds to many of the comments made earlier, in this report.

Note: In everyday English usage, **Examine** and **Inspect** are usually considered to be interchangeable, *(as given in the Oxford English Dictionaries)*, however, the same RAF Glossary of Terms defines *Inspect*, as checking the work carried out by another person.

The CAA, however, defines **Inspection** *(CAP 562, Leaflet 15-2, para 1.2.d).),* as "*the examination* (sic) *of an aircraft/aircraft component to establish conformity with an approved specification*". The same CAA reference *(para 1.5.c)*, gives **Certify** as the appropriate word for inspecting work carried out by another person.

It should be remembered that the original inspection/examination procedures and their definitions were aimed at maintaining the aircraft in a serviceable flying condition, during the designed or actual military life of the aircraft. The continued flying of aircraft, beyond this original anticipated design life may mean that more detailed inspection procedures have to be specified to cater for the natural and the environmental ageing of the aircraft components, in the case of this report, the wiring system.

Implicit in carrying out such a survey, as defined above, is the requirement to take any necessary remedial action to rectify all defects found.

Environmental damage to wires (SWAMP areas)

Wiring which is exposed to the natural elements, e.g. in undercarriage or flap bays or to the aircraft specific contaminants, e.g. engine bays, fuel, bays, hydraulic bays and the aircraft belly, will be subject to much greater stress from these environments than that that experienced by wiring in the remainder of the aircraft. These areas are described in American aviation parlance as SWAMP or **S**evere **W**eather **A**nd **M**oisture **P**enetration areas, which very adequately defines them.

When wiring is contaminated with the various pollutants found in these areas, examination may well require cleaning of all cable surfaces before an adequate assessment can be made. To achieve this, it may be necessary to break down the cable harness to allow adequate access. Breaking down of cable assemblies, is not normally carried out, during maintenance, but the requirement must be driven by the conditions found, in situ. Maintenance personnel should not be inhibited by the prospect of damaging the wiring, simply by breaking down harnesses. **If the wiring cannot tolerate breaking down from the harness, it is probably already in a less than serviceable condition.**

Electrical faults deriving from wiring problems

The deterioration of the insulation of Pren wire, in particular, but also applicable to other wire types, presents the potential for random fault conditions induced by voltage tracking between adjacent wires.

Faults of this nature, encountered by the author, have been stray voltages, where localised tracking of voltages has occurred. This has almost universally been due to direct water/moisture contamination of the outside of the wire insulation, which is already significantly aged. The problem of 'wicking', as described earlier, can only make this situation worse.

The fault condition voltages, i.e. those measured where they should not occur, have always been on the 28 volt DC system and are usually well below the bus-bar voltage, (up to say, 10 volts). This tends to suggest that even with water/moisture contamination of degraded wire, there is some residual insulation, providing a relatively high resistance path between adjacent wires, allowing a very low current flow and therefore voltage drop. Even where wet voltage tracking has been found, no instances of functioning of the adjacent circuit have been encountered, other than warning bulbs glowing dimly, due to the low voltage and therefore current levels.

A quote from the RAF Air Publication 4343C, Electrical Manual, relating to the wire's ability to withstand fire damage, tends to confirm this:

"Polychloroprene does not support combustion, and the inner glass braid provides for short emergency service after the polychloroprene has been rendered inoperative as an insulant either by mechanical damage or incineration."

Unfortunately there is no quantification of this statement.

It is also true to say, however, that a direct or minimal resistance short circuit, between adjacent wires could occur, with all its implications of unwanted circuit functioning.

Where the voltage tracking is due to water/moisture contamination of the wires or wiring harness, fault conditions will often disappear as soon as the wiring is disturbed, during fault diagnosis and will disappear completely, if the wires are suitably ventilated and dried.

With Nyvin and Minyvin wire, the more common type of fault is due to chafing of adjacent wires or between wires and structure. This can lead to direct short circuits, intermittent *(bouncing)* short circuits or build up of charred material caused by very short duration arcing of conductors. With water/moisture contamination, the results are similar to those with Pren wire.

There has, in recent years, been a focus on these kinds of problems leading to explosive flash-over’s caused by high current shorts, due to the phenomena known as “wet arc tracking” and “dry arc tracking”. The focus has been on modern thin-wall insulation cables, in particular, those with Kapton insulation. Study of various published wiring reports indicates that both the phenomena were known and understood, even in the 1950s, but mainly relating to High voltage systems, such as the National Power Grid. No published evidence has been found to indicate that aircraft wiring, of the period being discussed, would be subject to these problems.

During the 1950s, more use of Alternating Current systems came into aircraft design, at various voltage levels. Where there are AC voltage systems on an aircraft, these were often, though not universally, wired with Prenmet screened cable, to provide screening and reduce electrical noise from motor-driven rotary inverters, which were often used as the A.C. power source, where alternators were not installed. Prenmet cable is a single core of Pren, with an outer cover of braided tinned copper wire, but no outer insulation jacket. As the braid will normally be tied to aircraft ground, at termination points, this will prevent any voltage leakage to adjacent wires, even though there may be some very low level current flow, (below the fuse or circuit breaker rating), to ground, via the screening. Prenmet was superseded by Nyvinmetsheath and Mininyvinmetsheath, which both had a braided screen and an outer jacket over the basic wire.

Mechanical damage to cable insulation of any type, particularly due to abrasion or fretting on adjacent structure, can be the cause intermittent short or open circuits, which can be very difficult to trace.

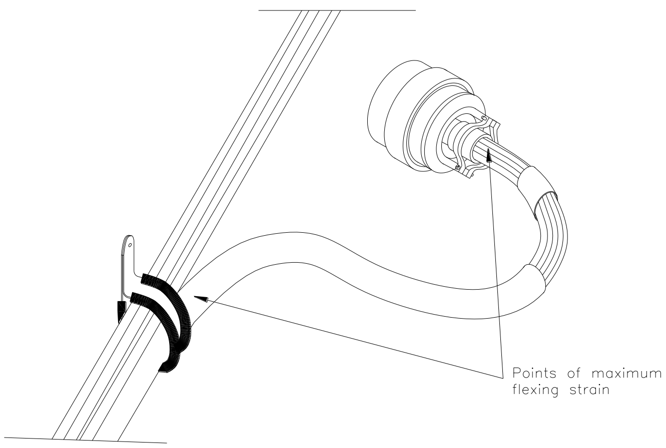
The breakage of individual strands of conductors at termination points whether by loss of support material, corrosion or mechanical damage, can lead to localised over-heating problems and further breakdown of terminal blocks and other equipment. Therefore all places where insulation sleeves have deteriorated or corrosion is apparent should be closely investigated.

Soldered joints can, over time, suffer from the natural migration of tin from the solder, leading to poor quality or “dry” joints. This, together with vibration, can lead to the development of intermittent high resistance connections at termination points. These intermittent faults can cause rapid changes in current, especially in high load circuits such as motors. Whilst modern installation techniques rely on the use of crimped terminations, there will still be soldered connections in use, particularly within original items of electrical equipment.

One item of electrical equipment in common use on British aircraft of the period being considered, was the Suppresser or Filter unit, which was used in generator and motor circuits, to remove noise produced by sparking brushes and prevent radio interference. There was a range of different sizes, to suit particular applications, but all had a similar layout. The filter comprised a die-cast box, with an internal supporting layout for inductor and capacitor components. The unit is entirely passive, as its only function is to remove unwanted electrical noise spikes from the circuit wiring. However, due to the age of these components, which are unlikely to have ever been changed, in their service life, internal problems do occur. Capacitors can leak, leading to internal damage, which can then cause short circuits. The thin wires attached to the capacitors, which are supported by rubber grommets, can have dry connection joints and can also, over time, break due to aircraft landing loads, allowing intermittent connection. The internal brackets supporting the inductors can also break, due to these loads, allowing further movement and creating the risk of short circuits.

Flexible wire harnesses, which are disturbed frequently by servicing requirements, such as equipment removal, or by designed movement of components, such as control columns, can cause work hardening of the copper conductors and lead to breakage of the individual strands, within the wire insulation, without failure of the insulation. This can occur, particularly, at the point of cable entry to connector cable supports or at the flexing point of a harness, which is designed to move with use and may give rise to intermittent faults. *(See Fig. 24).*

Fig 24 - Areas stressed by cable flexing



In aircraft using Pren, as the general purpose wire, a version called Flexpren was introduced for flexing applications, where a high number of thinner gauge wire strands for any given current rating was used, to give greater flexibility. This was only produced in the smaller gauge wires. In aircraft using Nyvin wire, a product called Instaflex was used.

When assembling a floating connector at the end of such a harness, a slight longitudinal twist, relative to the connector's final position, should be introduced, to absorb any excess bouncing of the cable. This is achieved by the position of the cable clamp and backshell relative to the connector keying. Note that the twist should not be so tight as to create strain on the harness.

Electrolytic Corrosion and Voltage Tracking

In some aircraft, there is evidence of localised electrolytic corrosion, (white powdery corrosion) at many points where wires touch, or run adjacent to local structure, or items such as terminal block mounting cases and lids. This is believed to be due to breakdown of the wire insulation and tracking of voltages, with very low currents into the structure, (as an earth return), particularly in environments, which are prone to damp conditions, e.g., Cockpits, Undercarriage and Flap bays. Given sufficient time, this can lead to penetration of metal structure.

Inspection, repair and prevention of damage to aircraft wiring

The above comments have been produced to provide a basis on which the condition of particular aircraft wiring systems and materials, relating to a particular historical period of British aircraft manufacture, can be critically assessed as to serviceability. It is not designed to be exhaustive in content, but to give an indication of the areas where potential for wiring problems exist.
When aircraft of the type being considered were built, they were designed with an operational life and wiring, in particular, was considered a *'fit and forget'* commodity, which, apart from modifications, would last the life of the aircraft. Military aircraft, which have moved into civilian ownership, are extending the life of aircraft well beyond the original design life. Recent concerns on the condition of wiring in civil transport aircraft have raised the need to give more thought to this necessary and ageing material in these and all types of aircraft.

It should, however, be remembered that the age of an aircraft does not necessarily condemn all the wiring as being of the same age or in suspect condition. Any examination of wiring systems, of this age, must be looked at critically, not only as to their current condition, but also in respect of their continued serviceability.

There is no easy answer to defining a method of examination and repair of cable harnesses, in any particular situation, as inappropriate handling of bundles of wires can stress any wiring or insulation, which is already in less than perfect condition. Each aircraft should be treated as a unique situation. The aim must be, however, to produce a fully safe and serviceable wiring system on the aircraft. Consideration should, therefore, be given to the removal of obsolete or unused systems or rendering them inoperative. This may be either by disconnection of all electrical supplies to those systems, as well as by disconnection or deletion of some portions or all of the unused wiring.

A considerable amount of work has been carried out, in recent years, to investigate the problems of ageing wire, particularly in large commercial aircraft. This includes the development of programmable circuit protection devices, which can detect any variation from the normal current load, for a particular circuit, rather than just a large over-current, which will detect the onset of insulation breakdown. Other systems have been developed, which test the wiring, in situ, using specialist electronic test equipment, over and above standard multimeter and continuity testers. Both these approaches are likely to be very expensive to develop and difficult to apply to small numbers or even single example aircraft types, such as those operated in the Permit to fly category.

Visual inspection of wiring will, therefore, remain as the main method of examination for deterioration of the wire or insulation, for aircraft in this category. With ageing aircraft and wiring systems, a high standard of inspection is required. This may mean that the wiring system needs to be cleaned, to remove dirt, lint, contaminants and stray metal shavings, without causing further damage. This must be carried out using vacuum cleaner machines and NOT directed high-pressure air jet. The inspection must be carried out using high quality lighting sources and magnification aids, such as binocular magnifiers. This can be supported by the use of insulation testers, with a voltage rating suitable for the wiring working voltage, where their application is suitable. Several published reports on this aspect of examination have claimed that less than 25 % of the wiring can be examined by visual means. From the description of typical faults, given earlier, it should be apparent that most problems are likely to be encountered on individual wires at the exposed ends of wiring harnesses or on the outer layers of wires on wiring harnesses, which are readily inspectable and will, therefore, give a reasonable assessment of the condition of all wires within a harness.

Individual wires and cable harnesses are more prone to damage, in some aircraft areas, than in others, as indicated earlier and this is considered again later, under Zonal inspections. Consideration must also be given to the likely environmental conditions, which will be experienced by areas such as engine, flap and undercarriage bays and it may be considered prudent to replace all wiring in these areas, as a matter of course, during any restoration programmes.

Current servicing requirements for Permit aircraft are often derived directly from the original military servicing requirements. It may be considered desirable to review such requirements to expand the types, areas and frequencies of inspections to be carried out.

Part of the training of all aircraft trades personnel, not just electrical/avionics, should include the requirement to use every servicing opportunity to look at the condition of wiring, adjacent to the task in hand and report all instances of damage. In similar vein, all trades personnel should be trained in the need for prevention of drilled or cut material being allowed to fall onto wiring harnesses or in areas where it could migrate to such positions. All such debris must be cleaned from work areas. Personnel should also be taught not to place tools, equipment or themselves into positions which can cause strain or damage to any part of the wiring system.

Although mention was made earlier, of problems with wiring materials, such as cable ties and cable clips, replacement of these should form a part of routine aircraft maintenance *and not be seen as a problem peculiar to older wiring systems*.

An aid to assessment of an aircraft's wiring condition may be gained by detailed study of the aircraft's RAF Form 700 (the aircraft log book), when preparing an ex-military aircraft for a Permit to Fly. This can indicate recurring problems, which were not conclusively resolved, during service and may, therefore, indicate existing wiring problems. Some aircraft, which had completed their flying life, and then remained in service as Technical Training Aids, had, when examined by the author, a list of known intermittent electrical problems, which, by interpretation, were probably due to wiring problems. These problems had been offset, by disabling specific systems, to enable continued use of the aircraft, for such tasks as engine running. If these aircraft are subsequently returned to Flight Condition, these defects must be addressed.

Repairs to damaged wiring have, in the past, been carried out, by direct replacement of wires and terminations, either in part, or as a complete wiring system, using new Pren, Nyvin, or Minyvin wire. Local repairs, using over-sleeving of individual wires, with heat-shrink materials, or in-line splicing of replacement wire have also been used. The use of heat-shrinkable materials must, however, be carefully regulated to prevent heat damage to existing wiring, which may have a much lower temperature specification than the more modern repair materials.

More modern wire types may also be used for direct replacement, but consideration must then be given to the different stiffness and abrasion resistance (hardness) of these wires, as well as the differing insulation wall thickness, when being used with particular types of crimp termination or connector.

Some of the original design materials or components are still available commercially, but it may sometimes be necessary to consider newer design material for replacement, when carrying out rebuild or restoration programmes.

High maintenance standards and ***anticipation*** of potential problems will be the best method to achieve prevention of problems with ageing wiring, the latter aspect which may not have been part of the original design or standard maintenance practice. It was stated earlier that wiring systems were initially considered to be a Fit and Forget item. The extended life of ex-military (and other) vintage aircraft raises the question of reviewing current inspection requirements and periods, especially in view of their reduced utilisation and the extended calendar lives.

Remember that aircraft wiring and its associated components will deteriorate, even when systems are not in use.

Consideration should be given to periodic exercising of electrically operated systems, on low utilisation aircraft, to ensure correct operation and exercise moving parts of switches, circuit breakers, relays and other electrical components, allowing sufficient operation time to ensure components reach a normal operating temperature, if necessary.

A major factor, which effects wiring, particularly Pren type, is contamination by water or moisture. Once moisture has penetrated tightly laid cable harnesses, especially in closed areas, with little or no ventilation, there is little opportunity for the moisture to escape by evaporation or drainage. If aircraft are regularly kept in a hangar, in a reasonable warm/dry environment, there is probably a much reduced risk of contamination. Externally stored aircraft, even with protective covers fitted, will experience damp and humidity problems. All inspections of aircraft wiring, of any age, should consider water/moisture contamination as a potential problem and address the problem accordingly.

The information given in this report should be used, as a guide to problem areas and the nature of problems that must be looked for, in those areas.

The EWIS concept and Zonal inspections

The concept of treating an aircraft wiring system as a single entity, in its own right, has come about following investigation of the loss of aircraft due to wiring problems. The EWIS or Electrical Wiring Interconnect System was initially promoted by the FAA in the USA. Using this concept requires that, from the design stage, onwards, the entire aircraft wiring is considered to be a single system and subject to inspection and maintenance, as such. The additional use of Zonal inspections means that areas of high risk (engine, undercarriage bays, etc) can be inspected more frequently, though no more or less rigorously, than other areas and should be considered for introduction to aircraft servicing requirements for the types of aircraft being considered in this report.

Planning an Aircraft Rewire, Repair or Modification

Whilst the foregoing information is presented to provide knowledge to assist restoration projects, the following is offered as a possible way of planning a project. Accept that every task will be different and will require its own interpretation.

When presented with a total rewire, repair or modification project, it is necessary to formulate a plan to deal with the process. Typically, with a total aircraft rebuild, the only information about an aircraft's wiring is that given in the Aircraft Publication (AP), Volume 1 (General and Technical Information), for RAF aircraft. On some aircraft this may have been superseded by the Topic 1 of coded publications. For American aircraft, the information will be given in a Technical Order (TO). The information will consist of a written description of the electrical systems and a set of circuit diagrams and wiring diagrams. The circuit diagrams give the theoretical circuit, whilst the wiring diagrams will give a diagrammatic presentation to illustrate the routing of the wiring through the aircraft. In each case, the diagrams are specific to one system and are designed to facilitate fault finding on a single circuit, not the manufacture of a complete aircraft system. There will, sometimes, be a presentation drawing to show the layout of the individual wiring harnesses, within the aircraft, which may be cross-referred to the Wiring diagrams.

With some aircraft, for example, the Spitfire, manufacturer's drawings are still available, from various sources, which will give layout drawings of the aircraft with a reasonable presentation of the total wiring routing and formation of wiring harnesses. As mentioned, very early on, many British aircraft electrical harnesses were produced to the Plessey Wiring System, by the Plessey company and it's sub-contractors. There were therefore individual drawings for every section of harness and for every variation, created by each and every modification. This may present a very daunting task to determine what is relevant. *Very little of this information remains available from BAe Heritage (Plessey successor company) and what there is will then only be released to CAA Approved Organisations.*

More likely, however, the only drawings available will be the basic circuit diagrams and wiring diagrams, contained in the relevant Aircraft Publication. From these it will be necessary to extrapolate an overall drawing to plan the layout of the aircraft wiring system. Any aircraft will have a number of standard circuits, such as Power and Generation, Engine starting, Lighting and Flight and Engine Instrumentation. The detail may vary, but all will have certain standard elements. The remainder of the aircraft systems will be for services, which depend on the aircraft's role.

To create a complete aircraft-wiring layout, start by drawing a large plan of the aircraft, with major equipment panels shown, along with individual terminal blocks and multi-pin connectors, all in their relative positions. From the circuit and wiring diagrams, draw in the relevant interconnecting wires. This may take a quite a few efforts to obtain an accurate and neat picture, but you will eventually have a drawing, showing the grouping of wires, between any items of equipment and their relationship to terminal blocks and connectors. It should then be possible to identify groups of wires that may be bundled together to create harnesses, for ease of manufacture, particularly if they are to be sleeved together. There may be one or two major harnesses for the fuselage, with other smaller harnesses between items of equipment and a similar arrangement for each wing. In the Plessey system these harnesses were identified by individual numbers prefixed by F, P or S, for Fuselage, Port wing or Starboard wing. The prefix and number is shown on the Wiring Diagrams. This suggested system of working is readily usable on simple, single engined, one seat fighter aircraft, but obviously becomes much more complex for multi-engined, multi-crew or aircraft with many roles. The process can be made easier by the use of CAD (Computer Aided Design) packages. This is the method used by the author, where possible. *(It was not practicable for the Vulcan, but fortunately drawings were available!)*

In original production, these harnesses would have been made up on jig boards, after development of prototypes, where every wire would be recorded in terms of a precise length, identification and termination. This is usually not possible with restoration or rebuilds, unless all original wiring is available and can be removed from the aircraft, to allow reverse engineering of the harness. Restorers often try to work out the wiring of an aircraft, by working from some significant point on the wiring system, say a major fusebox, or switch panel, laying in sufficient wire to allow for all the twists and turns of the 3D routing inside the aircraft. Unless accurate dimensions are known, the outer ends of the wiring are not terminated, until installed. This can be wasteful of wire, which has to be laid in over-length, or else results in wires of insufficient length to reach their destinations. Creating one or more 2D jig boards from the drawing created earlier and measuring and allowing for all the twists and turns of the wiring can be a very useful way of working. It will not, however, always be the best way to work, depending on the size and complexity of the aircraft, or particular harness, as it may be easier to build a harness in situ.

Having produced a drawing of the whole wiring system, a Wiring List can be produced, where every section of wire, in every circuit is uniquely identified along with its relevant destination and termination ends. There are numerous methods of identifying wires in a complex harness, which vary from a simple number, for each section of wire, as used on some wartime American aircraft, via various coding systems using letters and numbers. The latter has led to the ATA 100 system of aircraft wiring coding, which is now considered to be the aircraft industry standard and is favoured by the author, regardless of previous systems.

Having completed the Drawings and Wiring List, the designer/installer should have a very comprehensive knowledge of the particular aircraft’s wiring requirements. The ideas given above are general and every project will require its own specific system.

Repairs and modifications should be relatively easy, in comparison. Damaged wire should be identified from the Wiring Diagrams and can be directly replaced, though large areas of damage will need an approach similar to the restoration proposal, to identify all the requirements. Modifications, which tend to be add-on stand-alone equipment, such as radios are relatively simple, with the new design merely needing power sources and "plumbing" into the existing systems. Obviously modern avionics tend to have a great deal of integration of equipment, but this should require no more than standard wiring practices. Remember, however, the caution about the relative hardness of modern wire compared to older types, when mixing them together and manufacture and route the harnesses accordingly.

The reasons for writing the report

The writing of this report was prompted by the lack of knowledge, frequently encountered by the author and displayed by some aircraft owners, operators and maintenance staff alike, about the condition and serviceability of wire and cabling systems on vintage aircraft. There appears to be little understanding, by many, of the implications and consequences of the ageing of aircraft wiring and possible failures and consequences, due to physical or electrical breakdown. An attitude *of 'If it ain't broke, don't fix it',* seems to pervade in many areas, even though not being broken may be only a relatively short term condition, before catastrophic failure. It is hoped that the report may provide useful guidance to readers.

The report has not been written as a scientific examination of ageing wire and cabling systems, but rather as comment on the possible problems which may be encountered when assessing such material for serviceability, from a practical engineering standpoint, as previously experienced by the author.

Ben Cartwright
Airwire

Reference material

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AP 113D-1903-1 Ward Brooke terminal blocks	RAF	
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