Australian Government
Civil Aviation Safety Authority

AIRWORTHINESS BULLETIN

Flexible Hose Assemblies - Maintenance Practices	**AWB**	02-006	**Issue** :	2
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1. Effectivity

All aircraft equipped with flexible hoses, particularly hoses which carry flammable fluids such as fuel and oil.

2. Purpose

To provide guidance to aircraft operators, owners and maintainers regarding the application and maintenance of flammable fluid-carrying aircraft flexible hoses.

3. Background

Catastrophic in-service failures of all types of flexible hose in both large and small aircraft continue to be reported to CASA via the Defect Reporting System. These failures typically involve critical systems such as engine fuel, oil, braking and flight control system hoses.

Figure 1. Aircraft use many different types of flexible hose, and each hose type has specific maintenance requirements. (Picture: Eton Hoses)

Premature flexible hose failures can be attributed to chemical incompatibility with the system fluid, incorrect installation and handling, impact damage, inadequate maintenance, faulty manufacture and age. The hose and aircraft manufacturers inspection, testing and replacement recommendations cannot anticipate the entire range of in-service conditions that flexible hoses will be subjected to, and operators may need to establish more stringent inspection and retirement requirements to prevent hose failure.

3.1. Maintenance Schedules

Flexible hoses are aircraft components and Civil Aviation Regulation (CAR) (1988) 42V (1) requires that the performance and certification for maintenance, which includes flexible hoses, is to be carried out in accordance with approved data.

Operators who have elected to maintain their aircraft to CAR 42B, CASA Maintenance Schedule (Schedule 5) are still required to comply with the requirements of the applicable approved data. This data can be provided by the aircraft manufacturer, an Airworthiness Directive, Supplemental Type Certificate (STC), or the continuing airworthiness requirements for hoses installed under a CASR 21.M for an approved modification.

Engine, aircraft and hose manufacturers Service Letters (SL) and Bulletins (SB) issued in response to hose reliability issues should also be carefully assessed for applicability.

The consequences of a hose failure can have a significant impact on safety. This can include engine failure, flight control system failure and fire in the air. A maintenance program that does not include an in-situ periodic inspection that specifically identifies an inspection for flexibility, chafing damage, leaking, security and routing, as well as pressure test and/or a hose retirement schedule could be considered as deficient and should be amended.

Aircraft manufacturer's place a flight time in service, calendar period, pressure test and/or a disposal life on hoses, in addition to periodic in-situ inspections, for the following reasons:

- the difficulty of thoroughly inspecting every section of each installed hose via external in-situ inspection access,
- the difficulty in inspecting the interior surface of the inner hose lining, and
- the extent of the fatigue damage to the structural braid.

3.2. Hose Life.

All flexible hoses have a finite life. Several hose manufacturers mention FAA AC 20-7N General Aviation Inspection Aids Summary, which contained basic hose inspection procedures and recommended replacement of all engine compartment hoses at 5 years or at engine overhaul, whichever came first. These recommendations had proven effective over time. Several general aviation airframe manufacturers have now adopted these requirements, which typically include a 10 year replacement life for airframe hoses and the replacement of flexible flammable fluid carrying hoses in the engine compartment every 5 years or at engine overhaul, whichever occurs first.

Certain airframe hoses may have a recommended retirement life of much less than 10 years as listed in Chapter 05 in the aircraft manufacturer's maintenance manual or as mandated by an Airworthiness Directive or by Chapter 04 in the aircraft maintenance manual.

Be aware that there have been instances of hoses failing in less than 4 years' time in service. For example, Lycoming Service Bulletin No. 509 (Aeroquip Service Bulletin No.AA135) strongly recommends that Aeroquip 601engine rubber compound fuel hoses have regular periodic inspections, and imposes a recommended replacement life of just 2 years when used with low lead Avgas or Mogas.

Despite recommended and mandatory hose replacement requirements, it is the operator's experience which may ultimately determine if a more frequent hose replacement and more stringent inspection regime is required to ensure the continuing airworthiness of installed flexible hoses. Unscheduled hose failures should be investigated and a root cause analysis of the failure conducted to provide a basis for an appropriate hose inspection and replacement program.

During each routine in-situ hose inspection, the date of hose manufacture stamped or etched on the metal band on the hose should be checked against the date of the next pressure test and/or retirement date recorded in the aircraft log book. This is in order to determine if the hose will need to be tested or replaced during the current inspection or before the next periodic inspection, in accordance with the aircraft's maintenance program.

3.3. Hose failures caused by other system failures.

An analysis of the CASA defect report database shows that hose failure often follows a failure in another 'unrelated' system. There has been more than one case where a failing electrical component close to a steel braided hose produced arcing, which not only destroyed the electrical component, but severely damaged the steel braid of the nearby fluid hose. The electrical component was changed and the wiring repaired, but the damaged hose was not addressed and subsequently suffered a catastrophic failure after the aircraft had been released to service.

Flexible hoses also fail when the structural braid becomes weakened due to impact damage and fatigue. Fatigue failures can occur when the hose is subjected to repeated twisting or side loads, due to incorrect installation. Similarly, the hose could be subjected to high frequency hydraulic system pulses following an hydraulic 'silencer' or snubber failure, and from low frequency cyclic pulsations.

An in-flight piston engine exhaust system or turbo charger component failure can direct flame or hot gasses directly onto a nearby flexible hose. While the hose may not rupture at the time of the exhaust system failure, or show signs of any external damage, hoses which have been exposed to heat damage often fail shortly after the aircraft exhaust system has been repaired and released to service. Consider replacing any flexible hose which has been exposed to fire or extreme heat at the same time the exhaust system is rectified.

3.4. Hose failures caused by fluid incompatibility

All rubber hoses deteriorate due to heat, flexing, vibration, internal molecular changes over time and by reaction with both the internal and external fluids with which they come into contact. Subtle modes of failure occur when a rubber compound hose is incompatible with the fluid, particularly in regard to fuel hoses. Quality escapes by hose or aircraft manufacturers, the change to low-lead Avgas and using Mogas variants have also resulted in premature rubber compound hose failures.

Incompatibility between the hose and the fluid may be indicated by the hose cracking and leaking, or becoming soft, or fuel changing colour as it passes through the hose. In one case, newly manufactured rubber compound Avgas compatible fuel hoses were repeatedly flushed with Avgas prior to installation. The fuel colour had changed to yellow. Avgas soaked in the new hose overnight turned orange/red with an oily feel. The hoses were rejected on suspicion of incompatibility with Avgas.

Rubber compound hose manufactured to meet MIL-H-6000 D (now MIL DTL 6000D Amdt 2 as of 01 Oct 2014), DETAIL SPECIFICATION - HOSE,RUBBER, AIRCRAFT, FUEL, OIL,COOLANT,WATER AND ALCOHOL will soften and swell in contact with Mogas to the extent that the internal diameter of the hose will swell and shrink the internal diameter of the hose completely closed, severely restricting the flow of fuel to the engine, and causing engine failure. Although MIL DTL 6000 D states that hose made to the specification is suitable for fuel for aircraft engines, the standard identifies the reference fuel as US Military kerosene type fuels, not Avgas, or Mogas.

Any modification to the fuel system, including changing the fuel used from Avgas to Mogas, or incorporating a new or different fuel system hose material should only be accomplished in accordance with approved data which does not have conflicting requirements. Problems arise when an operator incorporates one STC which allows the use of Mogas via the Flight Manual Supplement (FMS) and then incorporates another STC involving the fuel system on the same aircraft which specifies only Avgas in the FMS. The second STC specifying Avgas in the FMS is the clue that the STC may use hoses which are not compatible with Mogas.

3.5. Hose design evolution.

The chemical family of Polytetrafluoroethylene (PTFE) and Tetrafluoroethylene (Teflon®) hoses appear to have overcome many of the problems associated with rubber compound hoses, such as shelf-life, deterioration due to chemical interaction with oil and fuel as well as hardening and cracking due to age and heat. Despite these advantages, PTFE hoses appear to be more susceptible to damage resulting from careless handing and incorrect installation than rubber compound hoses. Great care is required handling the hoses during installation, removal (including partial removal to gain access to other components) and inspection.
(Teflon® is a registered trademark of DuPont).

Fluid passing through a short length of PTFE type hose with a non-conducting inner liner will build up a significant static electric charge. This charge is powerful enough to produce arcing which burns holes through the inner PTFE type pressure liner, resulting in hose failure, typically indicated by weeping. Stainless steel braid in direct contact with the PTFE will not earth the static charge. Replacing rubber compound hoses with PTFE type hoses should be only in accordance with approved data, using only approved “conducting” aviation grade PTFE hoses.

Some types of PTFE hoses may also be more sensitive to minimum bend radius than rubber compound hoses and typically require a larger bend radius than the equivalent rubber hose. If the bend radius of any rubber or PTFE hose is too small, the inner hose wall is likely to ‘kink’, restricting fluid flow, severely weakening the hose and making it liable to fail prematurely, even if the hose is later ‘un-kinked’.

Both rubber compound and PTFE hoses can take on a permanent ‘set’ or shape (become less flexible) after some time in service. The inner liner can fail if flexed excessively or temporarily kinked during removal for testing for example, or while removing the hose or gaining access to remove and install another component.

Do not attempt to straighten hoses which have a ‘set’ shape and maintain hose shape during pressure testing, as any curved hose will tend to straighten when under pressure. Consider handling PTFE hoses as if they are solid or rigid lines. FAA SAIB NE-06-67 (Sept. 2006) Aircraft Engines Using Flexible Lines and Hoses That Carry Flammable Fluid.

3.6. Fire resistant and "fire proof" hoses.

Engine compartment hoses are required to be fire resistant. Terms such as 'fire-proof' or 'fire-resistant' should not be taken to mean that the hose is not affected by flame or heat. Such hoses have only been designed endure very high temperatures for a limited amount of time before rupturing. The FAA definition of 'fire-proof' is that the hose must withstand a direct flame for fifteen minutes under standard test conditions without failure. Hoses classified as 'fire-resistant' must withstand a 5-minute exposure to flame under the same internal fluid flow conditions without failure. (FAA AC 33.17-1A, Engine Fire Protection).

Fire resistance has been achieved in some cases by the use of slip-on fire sleeving or by encasing the hose in a fire-resistant silicone coating during manufacture, as found on certain Teflon/PTFE hoses. Some aircraft manufacturers have met the engine hose fire resistance design requirements by increasing the wall thickness of the hose. That is, by using a hose intended for a much higher pressure.

Any slip-on fire-sleeving, including any sleeving in addition to that specified by the aircraft or aircraft engine manufacturer, should be incorporated only in accordance with approved data including the applicable Technical Service Order (TSO). Fire sleeving must cover the end fitting as shown below. Be aware that slip-on fire sleeves can mask hose defects, and nicks and cuts in the fire sleeve. Unsealed hose sleeve ends can also admit and retain fuel, oil or moisture against the outer braid.

Figure 2. Contaminated fire sleeving *(Picture: Mechanic Support)*

Trapped water could result in corrosion of the hose lay-up wires or braid. Oil or fuel contamination on the inside of the fire sleeve will result in serious deterioration of the fire resistant characteristics of the sleeving.

3.7. Hoses manufactured in the course of maintenance (MITCOM)

Hoses may be manufactured in the course of maintenance provided the facility is approved to do so and has the approved data, correct tools and expertise. Hoses manufactured under MITCOM must conform to the aircraft's type design requirements and meet the current applicable Technical Service Order (TSO) or design standard for the intended installation.

Using hoses or hose materials other than those specified in the aircraft illustrated parts catalogue (IPC), a Supplemental Type Certificate (STC), or aircraft manufacturers service information, should be approved by a CASA 21.M Delegate and the approval should include the continuing airworthiness requirements for the hose. Hoses should be assembled and tested in accordance the techniques provided in the applicable approved data. FAA AC 43.13-1B CHG 1- Acceptable Methods, Techniques and Practices - Aircraft Inspection and Repair which is one example of CASA approved data which may be used to make replacement hoses.

UK CAA Leaflet 20-50 CAP 562 Civil Aircraft Airworthiness Information and Procedures; Hose and Hose Assemblies is considered a good source document from which to develop approved data when data from the hose or aircraft manufacturer is not available.

All hoses made under the provisions of MITCOM should be identified with a unique part number based on the original equipment manufacturer's part number, plus a locally generated maintenance facility number; the date of manufacture. (See also CAAP 30-4 (1.1) Appendix 9, Manufacturing Components In The Course Of maintenance, MITCOM).

3.8. General in-situ condition inspection guide

Vigilant periodic in-situ visual and tactile inspections are essential to detect various forms of deterioration which cause premature hose failure. This section provides a list of typical hose defects which should be used with other guidance, such as hose manufacturer's wall charts, engine and aircraft manufacturer's data, etc. depicting typical hose defects and causes for hose rejection.

NOTE: *The following pictures and text are provided as examples in the interests of aviation safety for illustrative and training purposes only. It should be noted that the text accompanying any picture may not be the actual causal factor(s) for the specific failure depicted.*

(a) Brittle

Picture: ATN-Aircraft Division

The typical piston engine oil hose consists of a rubber compound inner liner with a structural carbon steel braid covered with a grey woven fabric cover. Heat from the engine oil and the engine compartment will harden the rubber compound hose. Such a hose may appear to be serviceable and slight defects in the cover may not seem too serious (or be completely hidden under a fire sleeve) until the hose is flexed by hand.

Careful flexing of accessible sections of installed hose by hand to assess hardness or flexibility may well result in 'creaking' noises or a 'crackling' noise and feel. This immediately indicates that the hose rubber liner has failed, is unserviceable and should be removed before further flight. The discovery of a brittle hose before the planned replacement time may also indicate an incorrect type of hose for the application and should be investigated. The carbon steel wire braids in the hose pictured above have also been severely affected by corrosion.

Caution: Treat PTFE/Teflon hose as a solid line. (FAA SAIB NE-06-67).

(b) Twisted

Typically caused by incorrect installation, where, during final torqueing of the second union, the nut picks up on the back of the hose nipple fitting, and twists the hose.

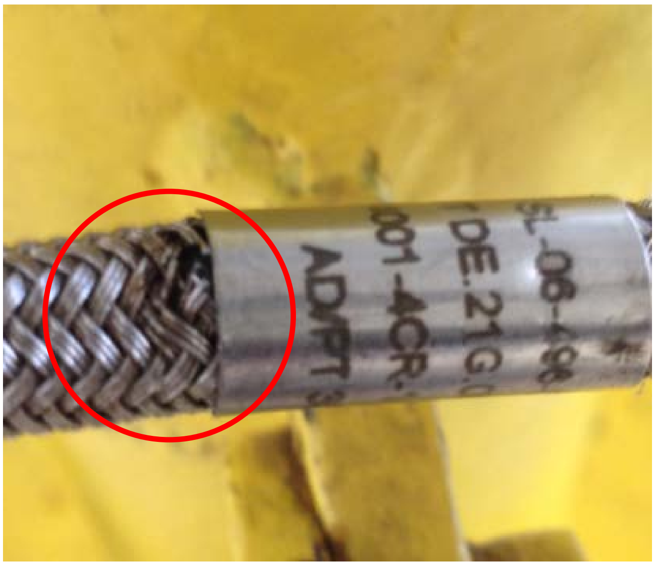
Twists cause permanent damage to the structure of the hose, and if undetected, cause restricted flow, local 'hot spots' and rapid deterioration of the inner hose liner or pressure vessel.

A hose which has been kinked during installation, or found kinked or twisted during inspection should be replaced before further flight.

(c) Kinked

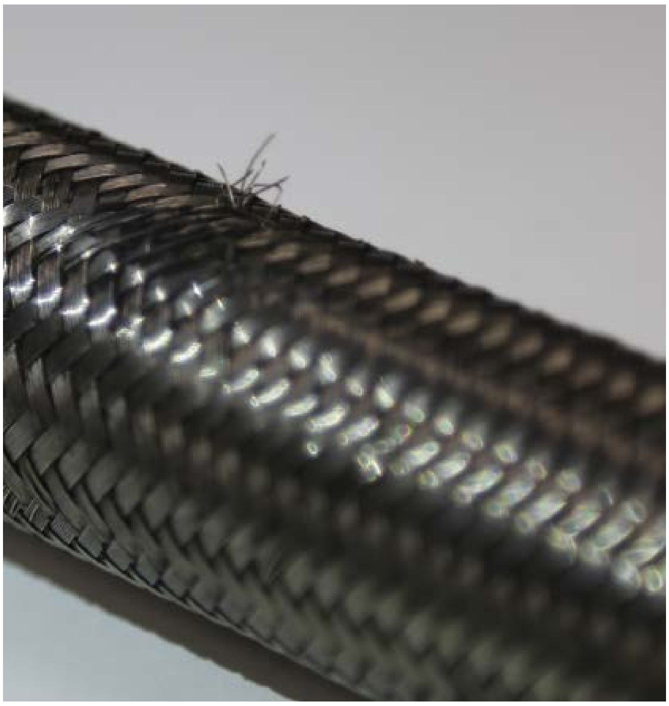
Typically caused by incorrect installation, attempting to bend the hose around a radius too small for the specified installation radius, or hose diameter. A new hose may initially resist kinking, but over time the hose wall may yield and collapse.

PTFE type hoses can fail after being kinked - even temporarily. During component removal and installation for example.



As with twists, kinks restrict flow and frequently result in local 'hot spots' and rapid deterioration of the inner hose liner or pressure vessel. These hoses should be replaced before further flight

Hose failure at or near the edge of the data tag can be an indicator that the hose was kinked at that point at some stage. (FAA SAIB NE-06-67).



(d) Broken Braids

Braiding is part of the hose structure. Some aircraft and hose manufacturers do not allow any broken braid wires at all, while others permit isolated random breakage of a braid wire.

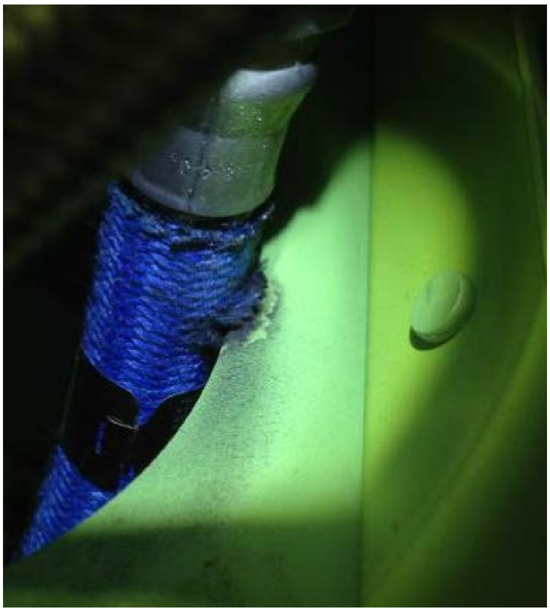
Hose and aircraft manufacturers seem to agree that if several wires are broken in any single concentrated area, or if two or more wires in a single braid are broken, it is considered cause for rejection.

Braid failures can be due to chafing and/or fatigue.

(e) Chafed

Hose in-flight failure and loss of system fluid due to the hose chafing and flexing under and adjacent to the 'P' clamp.

Chafing damage is usually a cause for rejecting the hose. Ensure the hose routing, clamping and securing scheme is in accordance with approved data.



Even slight changes in the way the hose is installed between the clamps and subtle end fitting alignment, fitting angle changes during torqueing and incorrect torqueing procedures etc. can result in loss of clearance between the hose and the aircraft structure and/or other hoses.

Hose (above) failed due to chafing against the structure (right).

Chafing is frequently difficult to detect before hose failure, because the contact areas are concealed and the aircraft maintenance instructions typically do not state how and where to check for hoses chafing.

Special hose chafing inspections are frequently issued via aircraft manufacturer's Service Bulletins and Service Letters. Chafing damage and failure often occur because the hose has been made too long (or too short).

Chafed PTFE/Teflon hose (above) with integral silicone fire sleeve. Damaged sleeve flap folded back (right) to show extent of damage.

Such damage not only severely reduces the Type Design fire resistance requirement, it allows moisture and other fluids to penetrate the stainless steel hose braid under the covering. Stainless steel braid will corrode when exposed to contaminants and denied direct contact with atmospheric oxygen.

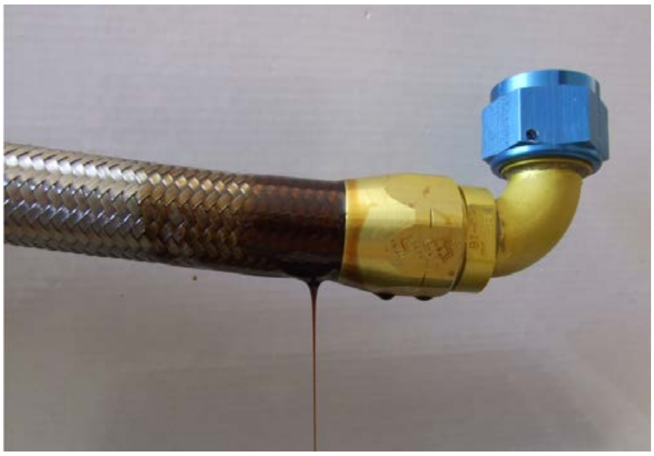
(f) Corroded

Corrosion and/or staining of the hose ends, particularly with regard to cloth braid covered carbon steel braided hoses, is reason to reject the hose.

End fitting corrosion and bulging cotton weave can be an indication of possible hidden corrosion damage to the steel wire braiding under the cotton cover, even though the cover may look sound. Any hose giving ‘creaking’ or ‘crackling’ feel or sounds when flexed should be replaced before further flight. (*Picture: ATN-Aircraft Division)*

(g) Contaminated / crazed / cracked

Instances of airframe rubber push-on fuel hose hardening and crazing at significantly less than half the aircraft manufacturer's calendar life of 10 years have been reported. The hose (above) was hard and cracked only on the side which had been exposed to paint overspray during aircraft manufacture, some 4 years previously. The hose wall was still soft and pliable on the unexposed side in the same section.



(h) Leaking

Any weeping/leakage from the end fittings that retain the flexible hose element or any leakage/seepage from any section of the hose is reason for immediate replacement.

(Picture: Mechanics Support)

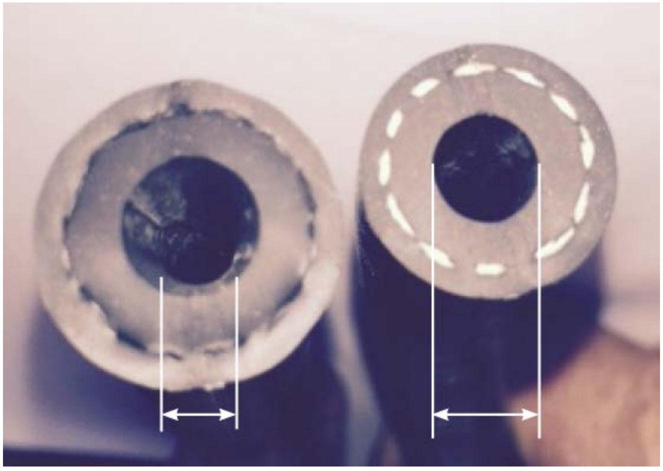
(i) Damaged fire sleeve

Be suspicious of any indication of damage to the fire sleeving. Particularly if the sleeve (and hose) have been exposed to fire/flame or exhaust gasses. Damage limits for fire sleeving may be provided by the aircraft or sleeve manufacturer. In the hose pictured, the fire sleeve was heat damaged, but the fuel hose inside was burnt through.

(Picture: Rennlist.com)

(j) Blistered / bulged

Blistered hoses may be the result of age, fluid incompatibility or internal layer separation. Check for any evidence of swelling or 'ballooning' along any length of the hose during testing or operation. Swelling Indicates catastrophic structural failure of the hose braid and the hose should be rejected immediately.



(k) Swelling / soft

Swollen / soft hoses usually indicate hose material is incompatible with the fluid the hose is carrying or exposed to. This example shows the result of MIL–H-6000 / MIL-DTL-6000 hose on the left after being soaked in Mogas overnight. The internal bore of the affected hose has reduced by approximately half of that of the same size MIL-DTL-6000 hose on the right. Avgas 100LL may have similar effects on certain rubber compound hoses.

When the Mogas is drained from the rubber hose and the fuel evaporates, the swelling will greatly reduce. However, because fuel leeches the plasticisers from the rubber, the hose will now become hard and brittle.

(l) Rubber Debris in filters

Failing rubber hoses may release flakes or particles of rubber which have broken away from the inner liner of the aging hose, contaminating the oil or fuel system. These flakes of rubber collect as non-metallic particles in filters and screens, and in oil jet lubrication orifices, resulting in lack of lubricating oil or fuel supply to the engine.

4. Recommendations

Follow the applicable Occupational Health and Safety (OH&S) precautions during maintenance and testing of hoses. Where aircraft manufacturers maintenance data is not available, SAE Aerospace Information Report 1569 (AIR 1569), 'Handling and Installation Practice for Aerospace Hose Assemblies'; and SAE AIR Report ARP 1658, 'Hose Assemblies, Installed, Visual Inspection Guide for' and Parker Aerospace Publication No. 106-SG1 and Parker Pamphlet 107 are recommended.

CASA makes the following additional recommendations in regard to flexible hoses which carry flammable fluids:

(a) All flexible hose assemblies in service should be vigilantly inspected and replaced at the intervals mandated by Airworthiness Directive, Chapter 04 of the aircraft maintenance manual or as recommended by the engine or airframe manufacturer or as required by the approved aircraft maintenance program.

(b) Unless the applicable approved data specifies otherwise, replace flammable fluid carrying airframe hoses at 10 year intervals and engine compartment hoses every 5 years or at engine overhaul, whichever comes first.

(c) Aircraft, engine and hose manufacturer's service bulletins should be evaluated by operators and/or have an independent engineering assessment made to determine if the information is applicable to the flexible hoses installed in the aircraft, and to determine if the data should be adopted into the aircraft's maintenance program.

(d) Carefully assess each installed or proposed STC involving any part of the aircraft's fuel system to ensure every STC is compatible with the fuel type and grade approved for use in the aircraft e.g. Avtur, Avgas or Mogas.

(e) Operators experiencing unscheduled hose failures should conduct a root cause analysis of the failure and establish a hose inspection and replacement program applicable to the aircraft and the operation to prevent recurrences.

(f) Keep rubber compound hoses stored away from sources of ozone such as running electrical motors, unless they are sealed in plastic sleeves. Hoses should be stored in individually sealed plastic sleeves below 26 ºC. Storing rubber fuel hoses which have been in service may require filling with a preservative (such as engine oil) to temporarily replace the plasticisers leached out by Avgas/Mogas and help prevent the rubber liner from drying out and cracking.

(g) Excessive flexing should be avoided during handling and storage of any hose particularly hoses which have been in service. Maintain hose ‘set’ shape when removed for the aircraft to prevent excessive hose flexing.

(h) Replace any flexible hose that has been exposed to flame or hot exhaust gasses before further flight.

5. Enquiries

Enquiries with regard to the content of this Airworthiness Bulletin should be made via the direct link e-mail address:

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or in writing, to:

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