Australian Government
Civil Aviation Safety Authority

Airworthiness Bulletin

AWB 85-024 Issue 3 - 10 June 2021

Robinson R22/R44 Engine Exhaust Valve and Valve Guide Distress

An Airworthiness Bulletin is an advisory document that alerts, educates and makes recommendations about airworthiness matters. Recommendations in this bulletin are not mandatory.

1. Effectivity

Robinson R22 Beta II, R22 Mariner II, R44 Raven I and R44 Cadet Helicopters fitted with Lycoming O-360 and O-540 series engines.

2. Purpose

To advise owners, registered operators, pilots, maintenance organisations and Licensed Aircraft Maintenance Engineers of the increasing incidence of premature exhaust valve and valve guide wear.

A failure to observe adverse indications or unusual behaviour of the engine may result in the situation developing to a point where cracks or chips can form around the edge of the valve face causing partial or complete loss of cylinder compression and degraded engine performance.

A clear understanding of all potential causative factors needs to be established before any permanent solutions can be implemented through design, manufacturing, operational or maintenance changes.

At this time, the airworthiness concern described in this Airworthiness Bulletin is not considered an unsafe condition that would warrant Airworthiness Directive action under Part 39 of the Civil Aviation Safety Regulation 1998.

Figure 1

Figure 2

Combustion Chamber view on Exhaust Valve/Seat and Valve Chipping

3. Background

Some industry participants are seeing an increase in incidence of premature engine cylinder removals due to exhaust valve and valve guide wear. The condition predominantly affects R22/R44 Heli Mustering operations across the northern / high ambient temperature regions of Australia.

In several cases cylinder changes have occurred within the first 100 hourly inspection following pressure readings below 60 psi during cylinder compression testing, (Lycoming SI No. 1191 refers).

It has been theorised that this condition is related to the change in grade of aviation gasoline (AVGAS), in particular the perceived introduction of higher levels of aromatics and reduction in lead. This point is discussed further in Section 5.

Several engine cylinder/valve examples with wear indicative of burning or compression leaks were sent to the Lycoming laboratory for analysis. All exhaust valves were coated with combustion residue inward from the rim to the beginning of the neck with some having patches of carbon on top of the combustion residue. No anomalous elements were identified however, occasional evidence of exhaust valve guide alloy transfer to the valve stem was seen when examined by scanning electron microscope (SEM).

Lycoming Engines and Robinson Helicopter Company as the Type Certificate (TC) holders for affected aeronautical products have invested considerable resources, time and effort to identify causal factors and solutions. The US Federal Aviation Administration (FAA) as the TC issuer for both the airframe and engine have also been engaged during each phase of the related investigation program.

Issue 3 of this AWB summarises investigation actions and findings and updates reference materials and recommendations. Minor editorial changes are also made throughout the text for readability.

4. References

RHC POH insert – HOT CLIMATE COOL DOWN PROCEDURE

Lycoming – Service Letter (SL) No. L282 – Australian Fuel Testing

Lycoming – SL No. L171 – Spectrometric Oil Analysis

Lycoming – SI No. 1191- Cylinder Compression

Lycoming – SI No. 1070 – Specified Fuels for Spark-Ignition Gasoline Engines

Lycoming – SI No. 1014 – Lubricating Oil Recommendations

Lycoming – Service Bulletin (SB) No. 301 – Service Limitations for Valves

Lycoming – SB No. 388 – Determine Exhaust Valve and Guide Condition

Lycoming – SB No. 634 – Cylinder & Head Assy Serviceable Life

CASA AWB 85-023 – Piston Engine Spark Plug Insulator Cracking

CASA AWB 85-025 – R22/R44 Engine Intake Valve and Valve Seat Distress

Note: Refer to the latest published revision

5. Investigation Program

Australian Fuel Testing

Refer to Lycoming SL No. L282 for a synopsis of Australian Fuel Testing.

Test Program - As indicated within the SL a test program compared the operating characteristics of a current configuration O-360-J2A engine on several fuels while instrumented to enable comprehensive data acquisition and analysis via a proprietary system made by AVL, Austria.

The program was conducted at various engine speed (RPM), engine power (OBHP) and temperature test points. In-cylinder pressures during steady state operation on each fuel were measured and recorded for analyses.

The following table provides a summary of the combustion characteristics analysed.

Parameter		Description
1	maximum cylinder pressure and location	Measures in-cylinder pressure relative to top dead centre of the compression stroke. Any measurable change in pressure (bar) and/or crank angle (deg) can be attributed to a change in combustion characteristics between fuels.
2	cylinder pressure during maximum valve overlap	Measures in-cylinder pressure during gas exchange when both valves are open. If the in-cylinder pressure is higher than the manifold pressure during this valve overlap, intake flow reversion can occur.
3	10%, 50% and 90% mass fraction burn	Calculates the heat release or instantaneous energy release between fuels. A measurable difference in burn rate would be detected as a change in the crank angle (deg) corresponding to the integral heat release fraction (%).
4	indicated mean effective pressure (IMEP)	Calculates the net-work produced by the gas on the piston. A change in IMEP between fuels indicates a change in produced power.

Table 1 – Combustion Characteristics

The recorded data showed consistent combustion characteristics between each fuel tested with negligible changes at each test point for parameters 1 thru 3. Additionally, the change in horsepower, and thereby brake mean effective pressure (BMEP), measured by the dynamometer and IMEP calculated from the cylinder pressures was negligible between each fuel at each test point.

It is acknowledged that aromatics typically possess a slower burn velocity and higher adiabatic flame temperature than aliphatic hydrocarbons. An increase in aromatic content, therefore, may contribute to an increase in EGT. However, even with an aromatic content variation from 0.9% to 17.8% the results of each comparison test demonstrated that the combustion characteristics remained within the cycle-to-cycle combustion variability of the engine. It also needs to be acknowledged from a chemical perspective that the stoichiometric ratio of the fuel can contribute to a measurable change in EGT.

The derived data was also independently reviewed with no unexpected findings for fuels that meet the requirements of ASTM D910 or the equivalent UK Def Stan 91-090 specifications.

Design Considerations

For R22 Beta II, R22 Mariner II, R44 Raven I and R44 Cadet helicopters a common parallel valve cylinder and head assembly (P/N LW-13870) is utilised in the respective J2A and F1B5 engines. This differs from the R44 Raven II with the AE1A5 engine having an angle valve cylinder and head assembly (P/N LW-12993).

Whilst it is acknowledged that there are various points of difference between the respective engine models, CASA considers this design configuration to be a contributing factor in reported occurrences.

The parallel valve layout dictates that the combustion chamber has a reduced hemispherical profile resulting in the valve stems, guides and associated actuating hardware being in proximity, compared to the angle-valve configuration. This impacts the thermal mass, and heat-dissipation pathways of the cylinder head. Uneven cooling and differing thermal expansion/contraction rates can result in distortion of materials causing misalignment of parts.

If the valve face and seat (when hot) do not remain perfectly concentric an even and complete seal will not occur during combustion. The heat path from the valve face through the seat and cylinder head is disrupted, interfering with the ability of the valve face to shed heat. This also enables tiny amounts of extremely hot combustion gases to leak past any area that isn't sealing properly. The result is a hot spot on the valve face. Once the valve develops a hotspot this sequence of events is perpetuated and progresses at an ever-increasing pace, leading to a pronounced cylinder compression loss.

Manufacturing Considerations

Lycoming has verified that the design of cylinder and head assembly P/N LW-13870 has remained stable for decades. Whilst the cylinder and head assembly part number remains unchanged this does not preclude minor alterations as long as the functional performance requirements of the type design remain valid.

Following the repatriation of some manufacturing and production line activities back into the Lycoming facility there is some evidence to suggest those changes may have aided in a down-turn of related issues being experienced by some operators.

Defect Reporting Trend

Figure 3 charts the Defect Reporting System (DRS) statistics for the period January 2013 thru March 2021, filtered for engine power section or cylinder section related defects on Robinson model R22 helicopters fitted with a Lycoming O-360-J2A engine and Robinson model R44 helicopters fitted with a Lycoming O-540-F1B5 engine.

The charted data does not support the hypothesis that the increase in related defects coincides with the introduction of 100LL Avgas (December 2015). Whilst a disproportionate reporting rate became evident around the start of 2018 this is outside any predictable lag period based on Bureau of Infrastructure and Transport Research Economics (BITRE) sector utilisation statistics and Mean Time Between Failure (MTBF) data for the affected cylinder part number.

A pronounced and sustained downturn in related reporting has ensued whilst remaining somewhat in-line with the seasonal operational trend however, CASA remains cognisant of external influences, such as COVID-19, which may impact data validity.

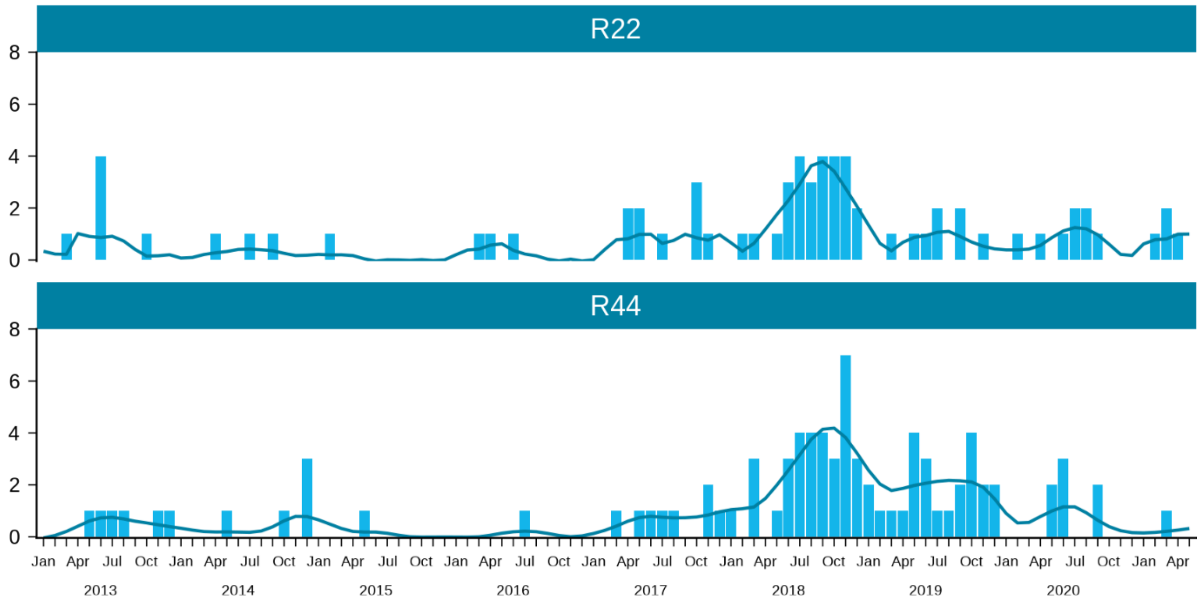

Figure 3 – CASA DRS Defects Reported (Qty/Mnth)

Monthly defects (bars) and 4Mnth moving Average (line)

Industry participants need to recognise that a true and complete picture can only be achieved on the basis of received defect reports. The issues CASA pursues, and the decisions made need to be data driven. This also needs to be balanced against the degree to which CASA, Robinson Helicopter Company and/or Lycoming Engines can or cannot control or influence identified causal factors to achieve a desired outcome.

6. Recommendations

A. Operating Procedures and Limitations

Air cooling alone, may be insufficient to adequately cool all cylinder components in some elevated temperature operating environments.

For the above reason, it is critical that all aircraft operational and performance limitations as given in the applicable aircraft Pilot's Operating Handbook (POH) and Engine Operation Manual are strictly observed.

During high ambient air temperature operations ensure that the engine cool-down period is adequate and provides a positive indication of a drop in the CHT with an appropriate margin if flight operations are to continue.

Refer Robinson Helicopter POH insert – "HOT CLIMATE COOL DOWN PROCEDURE" for related information.

Be aware that there is a cumulative effect of elevated temperatures on cylinder assemblies which will degrade the properties of those materials over time. Even a cylinder displaying a moderate CHT, can be suffering accelerated wear. Be mindful that a single probe CHT will not necessarily be indicative of all cylinders, nor represent even and consistent cooling of the entire cylinder assembly. CHT is also not necessarily indicative of actual valve temperatures.

B. Use of Appropriate and Qualified Fuel

The risk to the integrity of AVGAS in relation to being fit for purpose can occur at any point in the supply chain from the point of manufacture to final delivery to the aircraft, thus creating the potential to adversely affect aircraft systems and components.

Fuel suppliers need to verify that all product supplied to the market complies with Defence Standard 91-090 AVGAS and has been manufactured, stored and handled in compliance with Energy Institute 1530 aviation fuel quality system compliant supply chains to control contamination risks. Once the product leaves oil industry bulk storage locations and managed supply chains, testing for potential degradation or contamination is dependent on locally adopted standards and knowledge.

It is therefore of fundamental importance that every responsible organisation involved in AVGAS manufacture, supply, storage, transport, uplift and use has such systems in place in order to assure that the fuel is fully traceable and is preserved such that it continues to meet the requirements of the appropriate specification and end user purpose, whilst in its custody and/or its control.

The following elements need to be considered and addressed accordingly:

1. The fuel product being received is from an organisation that can demonstrate that all product supplied is compliant with the above referenced Standards.
2. Documents provided by fuel suppliers show the product traceability and integrity of each batch and that these documents are maintained

3. The design, construction and condition of customer storage and delivery tanks are verified as appropriate. Tanks are effectively identified, segregated, and dedicated to maintaining fuel integrity and preventing cross-contamination. Tanks also need to be water drained on a regular basis to maintain fuel integrity and reduce risk of water carryover to aircraft.
4. Ancillary equipment (filter systems etc.) meet appropriate specifications and are adequately checked and maintained to assure the delivery of clean uncontaminated fuel.
5. Fuel turnover is such that evaporative losses or heat induced degradation is kept to a minimum. Fuel held in tank storage for over 180 days without a receipt or drums over 12 months from fill date should be retested by a recognised laboratory accredited to ISO 17025 for aviation fuel testing.

C. Maintenance Regime

The aircraft and engine manufacturer develop their respective maintenance programs with the objective of providing reliable operation subject to “normal use and service”. These “normal use and service” conditions can be influenced and affected by several factors, such as, frequency of use (hours and cycles), techniques used in engine handling (particularly during starting and cool-down), atmospheric conditions during flight and on the ground, the type of flying being undertaken, adherence to published limitations and maintenance standards.

Where these “normal use and service “conditions vary the owner needs to review the maintenance program to ensure that it is appropriate and not deficient for their operational parameters. This may include the accomplishment of existing maintenance tasks at a reduced threshold or the introduction of additional inspections, checks and maintenance activities to assure appropriate continuing support for the aircraft and installed aeronautical products.

<u>What can be done to maximise cylinder valve and valve guide life?</u>

1. Air Induction Systems - Assess engine air induction system for properly sealed Air Box Assembly, Filter and Hoses, in addition to an appropriate clean and replacement regime, based on operating environment to prevent the entry of unfiltered air.
2. Powerplant Cooling System – Assess Cooling Scroll Assembly, Fanwheel Assembly, Oil Cooler, Plenum/Baffle Assemblies for condition and sealing to optimise cooling and prevent localised overheating.
3. Valve and Guide Condition Assessment
    a) Inspection – Concurrently with the accomplishment of the exhaust valve and guide condition check given in Lycoming SB No. 388C (or subsequent), inspect for the accumulation of carbon deposits around each intake valve stem, fillet and guide. Refer AWB 85-025 Issue 4 (or subsequent), for additional details.

b) Service limitations – At any time a cylinder is removed from an engine the valves should be inspected in accordance with the instructions given in paragraph 2. a. thru f. of Lycoming SB No. 301B (or subsequent).

c) For any valves that require refacing ensure that this is performed to a high precision standard to optimise sealing and heat transfer efficiency between the valve and seat in order to disperse the thermal load on the valve stem and guide.

d) For any valve guides that require reaming of the I.D. to remove deposits, select a reamer of the correct dimensions to remove the minimum amount of material. This will allow the guide to support the valve as much as possible and provide the maximum heat transfer from the valve to the guide.

4. Ensure proper fuel system setup and operation in accordance with the aircraft maintenance manual and engine manufacturers service instructions. Check that the fuel flow rate (lbs/hr) is appropriate.

   - R44/R44II (not Cadet) – min 64.4 lph @ MCP
   - R22 Beta II – min 33 lph @ MCP

   (as per relevant Lycoming Operator's Manuals)

5. Ensure oil type and grade is appropriate for the operating environment. Approved higher viscosity oils should be considered during periods of elevated ambient air temperatures and/or when oil inlet temperature approaches the recommended maximum during operation. However, this needs to be balanced against the cold flow characteristics of the oil which may restrict oil flow to certain components resulting in excessive friction and accelerated wear, particularly early morning engine starts at relatively low OAT during certain periods of the year. For example, the use of a multigrade oil extends the operating temperature range and provides superior lubrication during critical phases of engine operation. Refer to the latest revision of Lycoming SI No. 1014 – "Lubricating Oil Recommendations".

6. To ensure the engine is operating within recommended limits for normal operation, Lycoming strongly recommends that all engine instrumentation be calibrated annually. All instrumentation for manifold pressure, engine RPM, oil temperature, cylinder head temperature, and exhaust gas temperature, as applicable to the aircraft should be included in this annual calibration.

7. Engine Condition Monitoring

a) Regular Borescope Inspection - Enables timely and direct visual inspection of the combustion chamber, including the valves, cylinder head, cylinder barrel, and piston crown. The borescope permits a quick, inexpensive, unambiguous determination of whether the valves are healthy.

b) Spectrographic Oil Analysis – The oil in your engine not only lubricates, cleans, and cools, it can also provide one of the best tools for monitoring power-plant health.

Oil analysis should be used to complement the existing oil filter inspections. It is not a question of which one is better, since the two look at distinctly different aspects. Both could be considered essential to get a complete picture of what's going on inside the engine.

While oil filter inspections are usually the best way to determine if something is coming apart inside the engine, spectrographic oil analysis can be thought of as an early warning system capable of giving advanced notice of certain kinds of incipient problems, often long before they can reach a critical stage.

Exhaust valve guides are made of a high-nickel alloy, so accelerated guide wear will show up in oil analysis as increased nickel.

Lycoming Service Letter L171 refers.

c) Enhanced Engine Monitoring - Many engine-related problems can only be diagnosed while the engine is operating. Once it is in the shop, the opportunity for troubleshooting is gone. Various digital engine monitors are available which provide a way to see what is happening during the engine's combustion process, measuring, and recording information about the health of the fuel, ignition, induction, and exhaust systems. These systems can serve as an "early warning" device, pinpointing the location and nature of various types of engine problems (sometimes) long before they show up in other ways. Another use of engine monitoring data is for the identification and correction of poor power-plant management techniques which if left unabated can lead to premature engine wear.

These operational and maintenance efficiency gains can offset the cost of system installation within a relative short period of time.

7. Reporting

Report all instances of premature exhaust valve and guide wear to CASA via the DRS system available on the CASA website. Details of the maintenance history for the engine should be provided in addition to information concerning the method of failure detection, the location and condition of the defective parts.

Where possible, flight ops. parameters should also be reported i.e., OAT, RPM, MAP, CHT, Oil Temp, Est. Fuel Burn (lbs./hr.) together with any other information on possible triggers for the reported event. This information will facilitate a detailed review of potential failure causes and contributing factors.

8. Enquiries

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

AirworthinessBulletin@casa.gov.au

or in writing, to:

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