Australian Government
Civil Aviation Safety Authority

Airworthiness Bulletin

AWB 85-025 Issue 5 – 12 August 2021

Robinson R22/R44 Engine Intake Valve and Valve Seat 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.

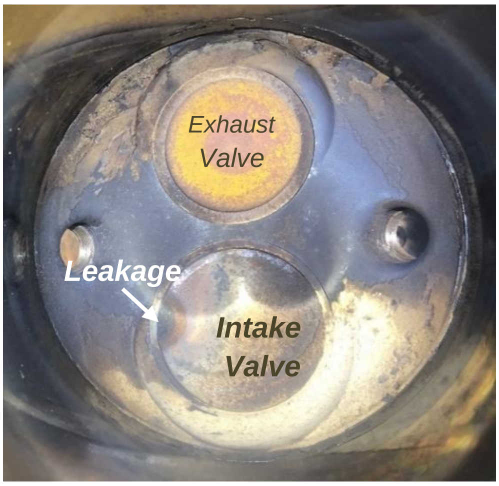
2. Purpose

To advise owners, registered operators, pilots, maintenance organisations and Licensed Aircraft Maintenance Engineers of the increased incidence of burned intake valves.

A failure to observe adverse indications or unusual behaviour of the engine may result in the situation developing to a point which results in an induction backfire, engine power loss and airframe yaw. In a severe event this could lead to several uncontrolled power and yaw reactions.

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 an Airworthiness Directive to be issued under Part 39 of the *Civil Aviation Safety Regulations 1998*.



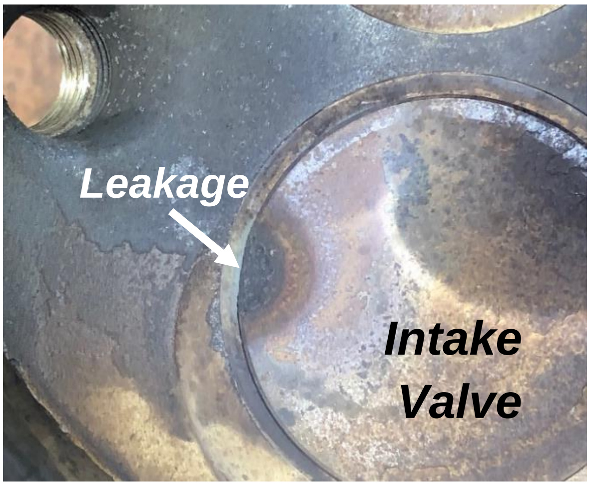
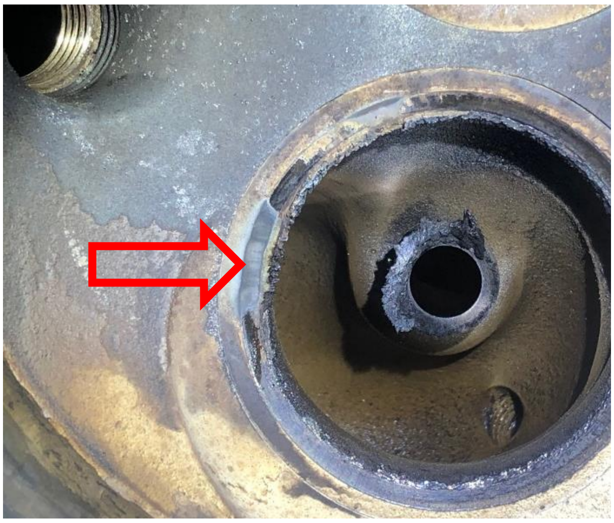


Figure 1

Figure 2

Combustion Chamber view on Intake Valve
Note crescent-shaped burn pattern due to severe and uneven heating at valve edge.
(Source: DRS No: 611852852)



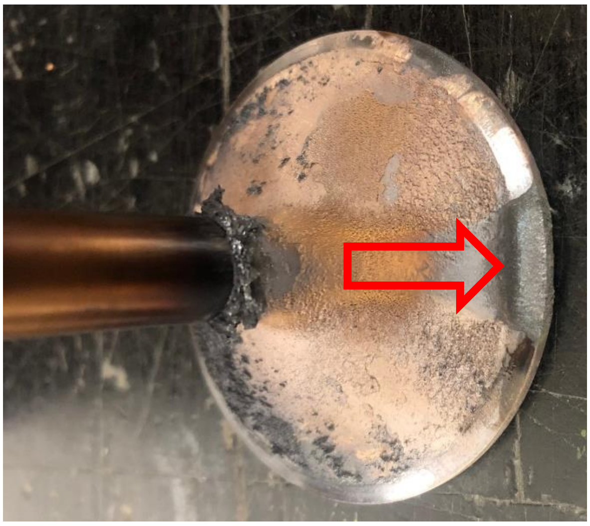


Figure 3

Figure 4

View showing corresponding Intake Valve seat face damage and carbon build-up
(Source DRS No: 611852852)

3. Background

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

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.

It has also been speculated that during extended ground operations at low Manifold Pressure (MAP) and high RPM, the intake valve rocker arm oil is migrating down the valve stem and accumulating on the induction side of the valve, leading to coking and carbon build-up.

The accumulated deposits are subsequently ignited with a flash-over causing valve and/or valve seat damage (erosion). This enables combustion to continue past the unsealed intake valve into the intake manifold with a percentage of the fuel-air mixture being consumed within the manifold causing an induction backfire leading to power loss and airframe yaw.

Several engine cylinder/valve examples were sent to the Lycoming laboratory for analysis with the source of carbon deposits confirmed to be from engine oil and not fuel or dirt contamination.

Both Robinson Helicopter Company (RHC) and Lycoming Engines have acknowledged this service issue and published guidance material accordingly. Refer Section 4 for related publications.

Issue 5 of this AWB references Lycoming SI 1280 and adds related information.

4. References

RHC - R44 I/R44 Cadet SAFETY ALERT – ENGINE INTAKE VALVES

RHC - Service Letter SL-78 – Field Service Data for Intake Valves

RHC – SL-59 & SL-73 – High CHT Indication

RHC POH insert – HOT CLIMATE COOL DOWN PROCEDURE

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

Lycoming – Service Instruction (SI) No. 1577 – Intake Valve In-Service Data

Lycoming – SI No. 1280 – Rotator Type Intake Valves

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. 634 – Cylinder & Head Assy Serviceable Life

CASA AWB 85-024 – R22/R44 Engine Exhaust Valve and Valve Guide Distress

Note: Refer to the latest published revision.

5. Investigation Program

<u>Australian Fuel Testing</u>

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

Fuel Analysis - As indicated within the SL the aromatic content of the fuels tested did vary between supply sources. Avgas producers trade off the chemical composition of the base fuel with the lead concentration to meet the octane requirement and other specification properties. With the reduction in the maximum allowable lead concentration going from 100/130 to 100LL, producers compensated by either using higher quality alkylates or by increasing the concentration of aromatics. As the other specification properties remained unchanged, this effectively caps the total aromatics levels to approximately 25%, (ASTM D910 Appendix X1.8 refers). This is also reflected in an excerpt from Coordinating Research Council (CRC) Report No. 657 (Figure 5) that conducted a survey of 100LL avgas and shows the range of aromatic levels in typical Avgas found in the field.

The aromatics level in avgas is neither required to be controlled nor measured by the avgas specifications. Despite this further independent analysis was conducted using methods described in ASTM D5769 to determine the benzene, toluene, and total aromatics, together with ASTM D6730 to determine the individual components in each fuel. The derived data was independently reviewed with the composition found in each fuel to be unremarkable with no unexpected molecules present in quantity or type.

The only conclusion to be drawn from the data is that each fuel analyzed met the requirements listed in the global aviation gasoline standards.

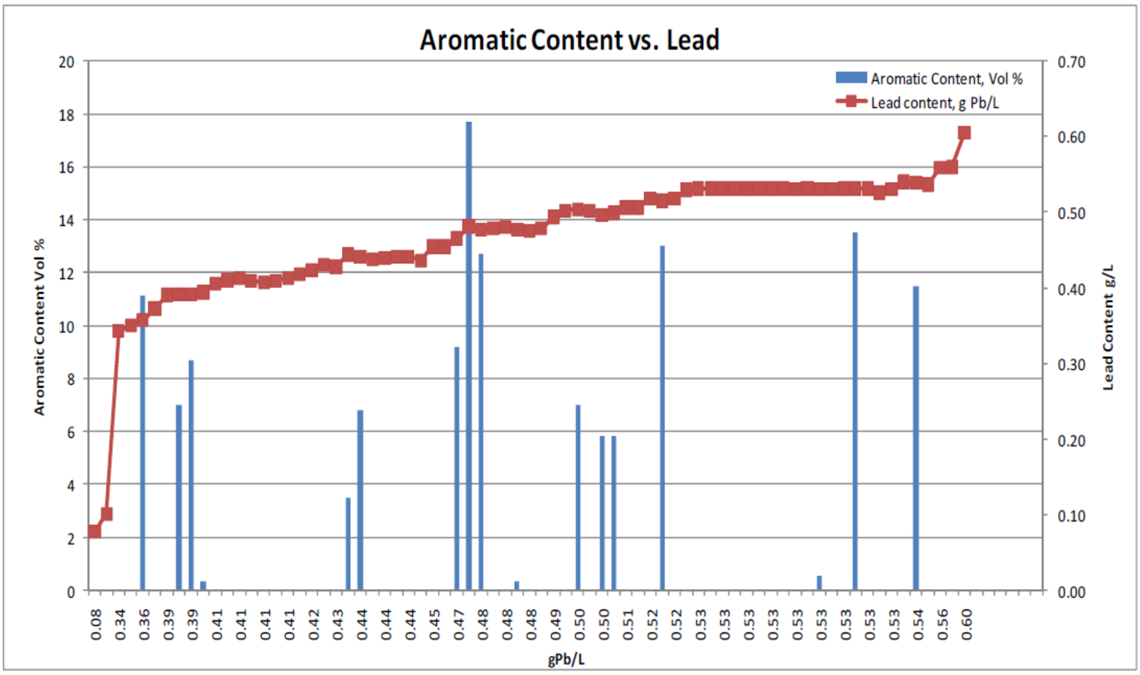


Figure 5 – Lead Content vs. Aromatic Content
(Source CRC Report No. 657 Rev. A, May 09, 2011, Page 46)

Test Program - The 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 operating points and environmental conditions including hot conditions at cylinder head, oil temperature and induction air limits, as follows.

Hot Condition Temperature Targets		
Hottest Cylinder Head	500°F - 510°F	(260.0°C – 265.6°C)
Oil Gallery Temperature	245°F - 255°F	(118.3°C – 123.9°C)
Induction Air Temperature	103°F - 109°F	(39.4°C - 42.8°C)

Figure 6 – Hot Condition Temperature Targets

The magnitude of changes in Cylinder Head Temperature (CHT) and exhaust Gas Temperature (EGT) need to be assessed against the inherent variability in engine operating parameters. Slight variations in engine speed, fuel flow, mixture distribution to each cylinder, and cycle-to-cycle combustion have an impact on the system. Even with the engine running at steady state conditions on US 100LL avgas, the measured CHTs and EGTs fluctuated within an operational tolerance of 4°F and 10°F respectively.

A consistent directional trend in EGT was noted between AU 100LL and AU 100/130. With the exception of the 2700RPM, 145 OBHP, hot conditions set point the temperature change across all cylinders was within the EGT operational variability discussed above. No directional trend was noted in the change in CHTs with the temperature changes across all cylinders and at each test point, within the CHT operational variability tolerance. The measured change in EGT of approximately 20°F (11.11°C) during the hot conditions test phase, remains within the typical variation expected during normal engine operation.

Changes in EGT can be expected with changes in engine power setting alone. For example, during the transition from a test point at 2700 RPM, 145 OBHP to 2652 RPM, 131 OBHP, (9.7% change in horsepower) the steady state temperature of EGT 2 and EGT 3 changed by an average of 31°F and 23°F respectively. Additionally, the sensitivity and variability in EGT is demonstrated in Figure 7 – Mixture Distribution Sweep, where manual leaning from best power to best economy results in an EGT increase of approximately 150°F. This is typical for the same cylinder head and valve configuration used in fixed wing applications.

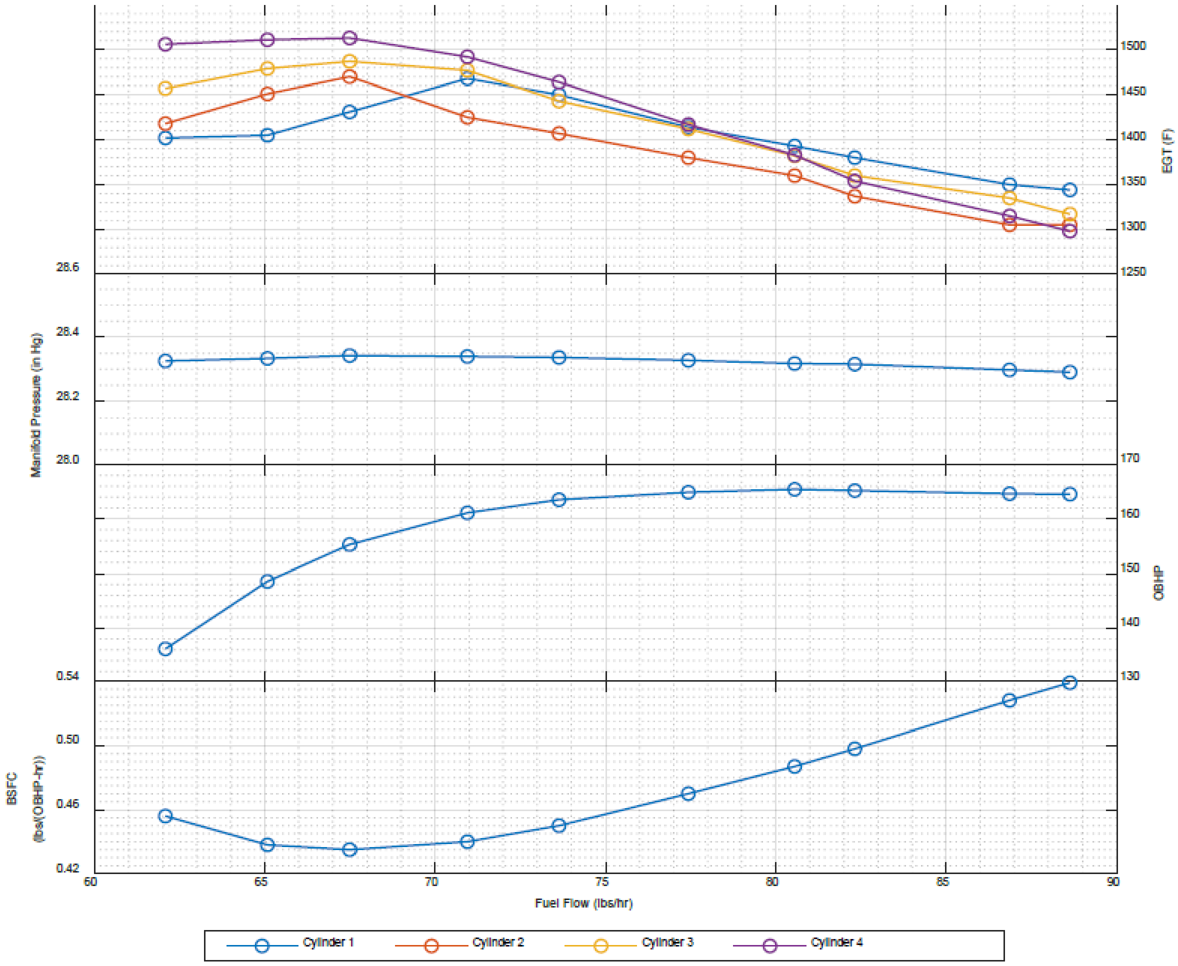


Figure 7 – Mixture Distribution Sweep

It is recognised that a variation in EGT can be anticipated when switching between fuels possessing different aromatic contents. However, for a fuel that meets the Avgas specifications where the aromatic content only varies from 0–18% v/v the magnitude of the change in EGT values has been demonstrated to be minimal and not expected to have an impact on the operation or durability of an engine, on its own.

Avgas Low Lead Future

There is a limit to which the effect of reduction in lead (tetraethyl lead) may be offset by the base alkylate and aromatic content to achieve the required Motor Octane Number (MON) for the fuel. Historically, the lead concentration typically must exceed 0.28Pb, g/L. With lead being a toxic substance that can be inhaled or absorbed in the bloodstream, alternative unleaded fuel formulations are being explored. This effort is being led by the Piston Aviation Fuels Initiative (PAFI) research program as a partnership between the FAA, aircraft and engine manufacturers, fuel producers, the EPA and industry associations.

For CASA, flight safety is of paramount importance in any switch to alternative fuels. Until a viable unleaded replacement fuel is found and certified, the current position will remain unchanged. It also needs to be recognised that the piston aviation fleet in Australia inevitably has to transition to an economical viable unleaded future.

In that regard CASA will be guided by the outcome of the PAFI program, the implementation strategies promulgated via the Federal Aviation Administration Unleaded Avgas Transition Aviation Rulemaking Committee, the ASTM International fuel specification and associated legislative requirements passed by the Australian government.

6. Recommendations

A. Operating Procedures and Limitations

Pilots should observe the following precautions:

Perform a complete run up and stabilised hover check prior to every flight. Do not initiate flight if there is an indication of engine rough running, induction backfire or sudden airframe yaw.

If any of the above symptoms are experienced during flight, discontinue the flight, and have an appropriately Licensed Aircraft Maintenance Engineer (LAME) check valve condition.

The LAME should listen for sound of leakage at each intake valve while performing a differential compression test in accordance with the latest revision of Lycoming SI No. 1191. A cylinder borescope inspection should also be performed as outlined in paragraph ‘C’ (below)

Note: If a leak path past an intake valve is detected, contact Lycoming Technical Support for further guidance. Refer to Lycoming SI No. 1577 for additional information and reporting requirements.

<u>Aircraft Performance Limitations</u>

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.

Powerplant limitations are given in Section 2 of the Robinson POH which identifies the Cylinder Head Max Temperature as 500°F (260°C). The colour code instrument markings for the Cylinder Head Temperature (CHT) identifies the Green arc from 200 to 500°F (93 to 260°C) with the Red line at 500°F.

The edge of the Red line identifies the operating limit and the pointer should not enter Red during any normal operations. These limitations need to be considered concurrently with the applicable Lycoming Operations Manual which states:

- Never exceed the maximum red line cylinder head temperature limit, and
- For maximum service life, cylinder head temperatures should be maintained below 435°F (224°C) during high performance cruise operations and below 400°F (205°C) for economy cruise powers.

Furthermore, Section 5 of the POH provides the following pertinent details on aircraft performance relative to operating temperatures:

- Satisfactory engine cooling has been demonstrated to an Outside Air Temperature (OAT) of 38°C (100°F) at sea level or 23°C (41°F) above ISA altitude.

Note: All associated aircraft performance data presented in the POH which is charted against OAT is limited to +40°C (+104°F).

Figure 8 shows a scatter chart of maximum OAT's from Engine Data Management (EDM) systems installed on Robinson Helicopters operating in Australian regions north of the Tropic of Capricorn.

The following items should be considered to reduce the impact of "hot" operations:

- Ensure operating parameters meet charted values.
- Fly the aircraft in accordance with the manufacturer's guidelines.
- Avoid manoeuvres which may interrupt/distort relative airflow for engine cooling.
- Plan operations around the coolest time of the day.

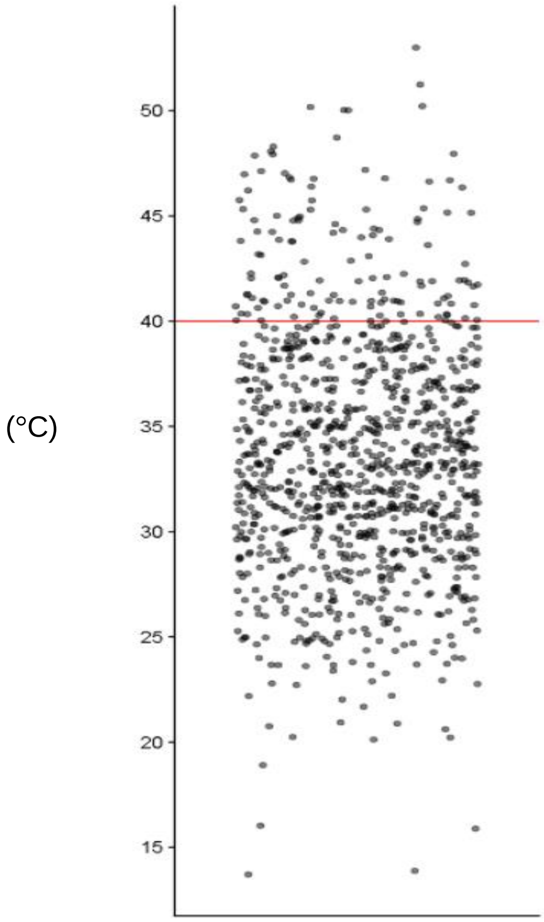


Figure 8 - Maximum OAT (°C) per Flight

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.

> For maximum service life of the engine, Lycoming recommends:
>
> - maintain CHT between 150°F and 435°F, during continuous operation, and
> - prior to engine shutdown idle until there is a decided decrease in CHT.

Operating Factors

Intake valve deposit formation, wear and leaks may also be aggravated by:

- ‘Hot Loading’ and/or ‘Hot Refuelling’ (extended ground operations) in high ambient temperature conditions. It is therefore recommended that wherever possible these operations are avoided or limited.
- Inadequate engine cool down prior to engine shutdown. It is recommended that an extended cool down regime is initiated to ensure that engine CHT is as low as reasonably practical prior to engine shut down. This may require several minutes of run time to maximise the benefit. If the ambient ground air temperature conditions impact a pilot’s ability to induce an adequate drop in CHT prior to engine shut down consideration should be given to suspending operations.

NOTE: Robinson has published a HOT CLIMATE COOL DOWN PROCEDURE for insertion within Section 4 of the POH to avoid potential unintended consequences resulting from inadequate engine cooldown during aircraft operations in hot climates.

B. Oil Type/Grade

Analysis has verified that the coke-like deposits on the convex side of intake valves was primarily derived from residual lubricating oil, (not fuel or air-borne contaminants). Coking can form as a thin-film layered deposit (varnish or staining) or in thick clumps. Determining the initiation source of coke formation is difficult as it can be attributed to a combination of influences including, but not limited to.

- operational conditions such as hot shutdown
- exposure to abnormally high conductive or convective temperatures
- prolonged aircraft inactivity leading to moisture absorption of coke deposits.

As indicated in Figure 7 there can be a wide variation in operating temperature. Selecting a high viscosity straight weight oil due to high daytime ambient temperatures may exceed the low temperature range of the oil during colder, early morning engine starts. Additive packages in multigrade oils extend the operating temperature range and provide superior lubrication of the engine.

To determine what grade of oil to use refer to the latest revision of Lycoming SI No. 1014 – “Lubricating Oil Recommendations”.

C. Maintenance

Cylinder Borescope Inspection

Implement regular borescope inspections as a first line of defence in detecting the onset of valve problems. The cylinder borescope inspection enables timely and direct visual examination of the internal cylinder components and should be used in conjunction with the “Differential Pressure Test” to assess the condition of the valves to identify visual signatures and abnormal operating patterns.

1. With the spark plugs removed, position the piston at bottom dead centre at the end of the intake stroke.

2. Insert the borescope through the upper spark plug hole and inspect the intake valve and valve seat.

3. Inspect for signs of leakage or damage indicated by localised discolouration or erosion on the valve face and seat circumference.
   See previous example images.

4. Remove intake pipes and move the piston through the intake stroke whilst observing the valve through the intake ports.

5. Inspect for accumulation of carbon deposits around the valve stem, guide and fillet. See Figure 8.

Figure 8 - Valve Intake Port

6. Deposit formation may also impact valve rotation which is essential to valve longevity. Valve rotation assists in equalizing the heat load around the circumference of the valve face and helps keep the valve and seat clean and free of deposits. A build-up of deposits will ultimately impact heat transfer efficiency with a consequential increase in localised temperature and hot spots.

   If you find a burnt/damaged valve, closely inspect the valve tip (where the rocker arm contacts the intake valve) and associated rocker arm 'toe' for linear wear marks, (indicating limited or no valve rotation).

   NOTE: In order to improve valve seating and minimize compression loss, a new intake valve, incorporating a rotator cap is available by retrofit in accordance with Lycoming SI No. 1280, Revision D. Alternatively, Cylinder Kit No. 05K29866 can be procured which includes the new rotator type intake valve configuration. Lycoming have also advised that new and aftermarket O-360-J2A and O-540-F1B5 engines shipped from Lycoming will have this new rotator type intake valve configuration incorporated.

7. Report all borescope inspection findings, including nil defects, to CASA per Section 7, (below).

<u>Maintenance considerations to maximise engine cooling efficiency:</u>

- Cooling scroll inlet metal lips-to-fanwheel clearance is within Maintenance Manual specification.
- Mixture control at carburettor is at full-rich position when mixture knob is fully in.

- Integrity of engine baffles and cooling panels.
- Cooling hoses are properly routed, secured, and in good condition.
- Correct spark plugs (Lycoming SI No. 1042 refers).
- Magnetos are properly timed.
- Integrity of exhaust riser-to-cylinder head gaskets
- CHT gauge calibration

Strict adherence to the aircraft and engine manufacturer’s maintenance schedule together with associated instructions for continuing airworthiness is essential for optimum performance and longevity of the engine.

Cylinder Assembly In-house Repairs

All maintenance involving the valves, valve seats and valve guides must be performed to a high precision standard to avoid concentricity/perpendicularity issues and suboptimal valve contact with seat face.

If valves require refacing, remove the minimum amount of material to clean up pits in the valve face or to correct any apparent warping condition. After refacing the total runout of the valve face and edge thickness must be within Lycoming published limits.

Whenever a new valve seat is installed, its matching valve guide must be replaced. This will assure concentric grinding of the new seat. Refer applicable engine Overhaul Manual for valve seat replacement instructions, dimensional limits, and necessary tooling.

7. Reporting

Report all instances of premature intake valve and valve seat degradation 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 in addition to modification status.

Operational 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 reporting of occurrences involving an engine backfire or aircraft yaw/twitch 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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