CAP Engine Break-in Procedures

A new or overhauled engine represents a significant investment, and proper engine break-in is vital to preserve this investment and maintain our valuable assets. The break-in period is the most critical time in an engine's life, with around 75% of normal wear occurring during this period. Proper break-in maximizes the performance and longevity of our aircraft fleet.

Objective of Break-In: The primary goal of the break-in process is to wear the piston rings to the cylinder surface, so they mate accurately, a process known as ring-to-bore seating. During break-in, metal-to-metal contact between the ring and cylinder wall is necessary to seat the rings properly. This contact is only desirable during break-in and not for the engine's remaining lifespan.

Cylinder Break-In Details: When a cylinder is new, its inner wall surface is not smooth. The break-in procedure aims to rub off high spots on both the cylinder wall and the piston rings. This process creates a tight gas seal necessary for normal engine operation.

- **Metal-to-Metal Contact:** During break-in, actual metal-to-metal contact occurs between the rings and cylinder wall. The rings' role is to seal the gases on the piston's top side from escaping to the bottom side and into the crank case. For this to happen, the rings must match the cylinder barrel's contour along their full diameter and width.

- **Heat Dissipation:** The cylinder barrel also undergoes some wearing to have a consistent contour along the ring's stroke. This consistent contour helps in quick heat dissipation through the rings, keeping the rings and piston cool. This results in a tightly sealed combustion chamber, leading to a healthy, efficient, and powerful engine with an acceptable level of oil consumption.

- **Break-In Requirements:** For proper break-in, the piston rings need to expand sufficiently to seat with the cylinder walls. This seating occurs when cylinder pressures are high enough to cause the piston rings to expand, typically achieved at power settings above 65%. This high pressure allows the piston ring to break through the oil film, permitting a certain amount of metal-to-metal contact.

- **Oil Consumption:** Once the rings match the cylinder walls, the break-in is complete, resulting in a noticeable decrease in oil consumption as gases no longer blow past the rings into the crankcase. The oil consumption rate stabilizes at a lower rate, indicating break-in is complete.

- **Break-In Timeline:** Break-in usually completes within 50 flight hours, with most ring seating occurring in the first 5-10 hours. Some experts suggest that 90% of break-in happens within the first hour, making initial engine operation critical. While ring-to-bore seating typically occurs within the first few hours, achieving optimal oil consumption may take over 50 hours of operation. You will observe a significant reduction in oil consumption during this period until the optimum rate is reached.

Avoid Glazing: Using low power settings prevents proper piston ring expansion, leaving an oil film on the cylinder walls. High combustion temperatures oxidize this oil, causing glazing, which halts the ring break-in process and increases oil consumption (often visible on the aircraft's belly due to a pressurized crankcase). Extensive glazing can only be fixed by removing and re-honing the cylinders, which is costly and avoidable with proper break-in procedures. Most fatal mistakes involve overheating the cylinders. If glazing occurs, report it to your AMO and have the aircraft serviced.

CAP Break-In Program:

These procedures will be followed for:

New Engines
Overhauled Engines
Cylinder Replacements (any number)

There is a distinction that must be made at the beginning of this process. Newly purchased aircraft will have already been flown at least once. However, we cannot make this assumption for aircraft coming back to us from an overhaul or similar repair. For these recently repaired aircraft, we must remain close to the maintenance facility for this first flight and the aircraft must be looked at by the vendor to ensure there are no leaks or other issues with the aircraft before the engine break-in process can continue. In this case, the pilot must use either the Fixed Prop (First Flight Only) Checklist or the Constant Speed Prop (First Flight Only) Checklist as appropriate to the aircraft. Only after performing this one-hour flight and having it subsequently inspected by the maintenance facility can it be released for further break-in sorites.

To be clear, these first flights do not constitute the "initial ground run" of the aircraft, which the maintenance facility must conduct before the aircraft is released to us to do any sort of flight.

The Engine Break-in Process will begin as CAP/LGM(PS&D) or the applicable AMO adds a discrepancy in AMRAD. This will classify all flights for this purpose as A9 flights. The aircraft may only fly break-in profile flights while in this status. All other mission types are **prohibited**. The aircraft will be closely monitored, with data analyzed and reviewed by CAP/LGM Plans Scheduling & Documentation. The AMRAD discrepancy will be closed once oil stabilization is achieved.

> CAP will use the following text in that initial discrepancy: "*During the new/overhauled engine break-in phase, certain operational restrictions and data collection requirements are mandatory. Only flight crew specifically authorized are permitted to operate the airplane during the break-in phase utilizing A9 sorties only. This discrepancy will be closed when CAP/LGM is satisfied that the break-in phase is concluded.*"

The AMO can request a review of the data at any time by contacting their CAP/LGM Maintenance Coordinator.

CAP pilots will use one of two checklists during all break-in flights, which dictate flight parameters for the aircraft, engine, and propeller. Proper adherence to these procedures is essential to avoid glazing and ensure correct ring seating.

Pilots must check oil levels before each flight, adding oil as needed based off dip-stick level and POH oil capacity requirements. Post-flight, the engine should cool down before rechecking the oil level. Checklists will capture data on cylinder head temperature, oil temperature, and oil consumption, which are indicators of proper ring seating. All data must be recorded manually while in the aircraft and then entered into a SmartSheet form linked at the bottom of each checklist after landing and cooldown.

It is highly recommended that at least two qualified CAP senior aircrew members take part in the flights accomplishing the engine break-in. The pilot's primary function is the safe accomplishment of the flight, and the second person can monitor and record all systems constantly for the duration of the flight. Cadets or additional crew members are not authorized in these flights.

Upon completion of 10 engine TACH hours, the collected data will be analyzed by NHQ for successful completion of the break-in profile through oil consumption and oil temperature stability. Ultimately, the Director of Aviation Support (CAP/LGM) will determine if oil stabilization has occurred and whether to release the aircraft for other missions, continue the break-in period, or send the aircraft back for further maintenance.

Lubrication for Break in

The respective AMO hosting the aircraft will ensure the following oil lubrication schedule is met. Spectral oil analysis (SOAP) will be performed at the 50-hour interval in all cases of engine break-in. The SOAP should be repeated 50 hours later, and then at each annual/100-Hr inspection thereafter. The oil analysis reports will be sent to LGM and retained in the aircraft engine logbooks for the life of the engine.

Use the following lubrication schedule during break in:

Hours on Overhaul	Description
0	Initial fill-up
10*	Change Oil and Filter
25	Change Oil and Filter
50	Change Oil and Filter
Every 50 Hours or 4 Months	Change Oil and Filter

Table 1 – Engine lubrication during break in

* 10 - hour oil change requirement not required for new Lycoming factory engines.

NOTE: Only mineral oil should be used for the break-in process.
Use only Phillips TYPE M 20W-50. If unavailable, use Phillips XC 20W-50 as an approved alternative.
For Lycoming turbocharged engines, use Phillips XC 20W-50 ashless dispersant oil only.

Expanded Procedures:

This section is dedicated to expanding the explanations to assist in checklist success. Please review the details here so that standardized action can be applied professionally in the aircraft during the actual stabilization of the engines and its components.

Fixed Pitch Propeller Checklist (See Attachments 1 and 2)

Purpose: To properly conduct the engine break-in following a new engine installation, overhaul, or cylinder replacement. This checklist is for any aircraft with a fixed pitch propeller. Record the required data fields on the checklist and input this data into the Smart Sheet form at the end of the procedure.

Use Attachment 1 during the FIRST FLIGHT ONLY for an aircraft with a fixed-pitch propeller. This checklist (attachment 1) is to be used when assigned by LG or PS&D following the installation of an overhauled engine or cylinders at maintenance facilities in your wing. The sortie is planned to last for TACH of 1 hour and the destination should be the origin airport. CAP is expecting the maintenance facility that performed the work to assist in the post flight review. So, trying to accomplish this during the business hours of the facility is to our advantage. If all parties agree the next flight would utilize Attachment 2 and the destination can be other than the origin. (e.g. return to home base flight)

Use Attachment 2 during all subsequent flights for the break-in period with a fixed-pitch propeller.

Pre-Flight Inspection additional focus – (complete normal pre-flight inspection)

Visual Inspection:

Inspect the aircraft for oil leaks, especially on the belly or unexpected compartments.

Take a picture of the aircraft belly for post-flight comparison to identify additional leakage.

Oil Check:

Check and record cold oil level on dipstick

Add oil to ensure the sortie starts with a full sump based off the POH.

Record both cold oil level and the amount of oil added on the checklist.

Density Altitude Planning:

Plan for an altitude that assures your ability to produce a minimum of 75% power and allows for safe traffic and obstacle separation.
In all cases do not exceed a DENSITY ALTITUDE (DA) of 7000ft DA. Anything more than 7000ft DA will PREVENT you from achieving a minimum of 75% power.

Understand that most engines cannot produce 75% power levels above 7000 ft density altitude. To achieve good engine stabilization the ability to achieve 75% power level is essential.

High elevation locations (especially during summer) should consider possible relocation of aircraft to lower altitudes during the break in process – consult CAP/LGM.

Determine and record power settings for both 65% and 75% power levels at planned density altitude.

When determining DA, POHs do not always refer to "75%" exactly in chosen altitudes when there is a choice our preference would be to choose higher power settings.

Example:

Pressure Altitude Feet	RPM	20°C BELOW STANDARD TEMP			STANDARD TEMPERATURE			20°C ABOVE STANDARD TEMP		
		% MCP	KTAS	GPH	% MCP	KTAS	GPH	% MCP	KTAS	GPH
2000	2550	83	117	11.1	77	118	10.5	72	117	9.9
	2500	78	115	10.6	73	115	9.9	68	115	9.4
	2400	69	111	9.6	64	110	9.0	60	109	8.5
	2300	61	105	8.6	57	104	8.1	53	102	7.7
	2200	53	99	7.7	50	97	7.3	47	95	6.9
	2100	47	92	6.9	44	90	6.6	42	89	6.3
4000	2600	83	120	11.1	77	120	10.4	72	119	9.8
	2550	79	118	10.6	73	117	9.9	68	117	9.4
	2500	74	115	10.1	69	115	9.5	64	114	8.9
	2400	65	110	9.1	61	109	8.5	57	107	8.1
	2300	58	104	8.2	54	102	7.7	51	101	7.3
	2200	51	98	7.4	48	96	7.0	45	94	6.7
	2100	45	91	6.6	42	89	6.4	40	87	6.1
6000	2650	83	122	11.1	77	122	10.4	72	121	9.8
	2600	78	120	10.6	73	119	9.9	68	118	9.4
	2500	70	115	9.6	65	114	9.0	60	112	8.5
	2400	62	109	8.6	57	108	8.2	54	106	7.7
	2300	54	103	7.8	51	101	7.4	48	99	7.0
	2200	48	96	7.1	45	94	6.7	43	92	6.4

In this example if you chose 4000 PA on a standard day you can achieve 77% at 2600 RPM or 73% at 2550 RPM. **Prefer 77%**. Remember we need to maintain a minimum of 75%. For the 65% setting at this altitude, you could achieve 65% at 2450 RPM but some indicators may not show that very accurately (steam gauge) thus using 2500 would be fine at 69%.

If you use the 6000 PA choice on a standard day again defer to the higher choice of 77% at 2650 RPM. In this example there is an actual 65% rating at 2500 RPM.

During Flight:

Take off and Climb Out: USE POH for all take-off settings. Once you achieve a safe obstacle clearance altitude or pattern altitude then, maintain a shallow cruise climb angle to achieve rpm requirements while avoiding overheating. (200-300 ft/min climb where obstacle clearance and noise considerations allow) Maintaining 200-300 ft/min climb rates at 75% minimum power setting allows more air to flow over cylinders and help cool cylinders.

Never exceed the maximum CHT per POH. The ideal range is 350-375F during all phases of engine break-in.

First Hour:

Cruise at appx. 75% power at or below 7000 DA (preferably 5000 DA if obstacle avoidance allows).

Record data every 20 minutes, see checklist for required postings.

Second and Subsequent Hours:

Vary power between appx. 65% and 75% per checklist, alternating every 20 minutes.

Record temperature and pressure readings. (per checklist)

Record the highest cylinder head temperature and cylinder position achieved in any monitored cylinder.

Additional Notes:

For carburetor engines with single-cylinder temperature monitoring, record the single cylinder's reading. (if applicable)

If the exhaust gas temperature gauge lacks numeric values, there is no need to record a value.

In all cases oil temperatures and oil pressures are to be monitored and recorded. Approximate the temperature and pressures when using analog gauges.

Issues & Descent:

If at any time readings are outside the green area for any system, return for landing and notify your AMO.

During descent, avoid sudden large power reductions to prevent extreme temperature changes. (shock cooling) Plan your descent reduce power gradually. Consider 100 RPM reduction every 5-7 minutes.

Consider using “high drag” configurations during descent to maintain higher power settings and temperatures.

Post-Flight Shutdown & Cooling:

Perform a normal shutdown and secure the aircraft.

Wait at minimum 1 hour for the engine to cool and oil to settle before checking the oil level.

Record the oil level reading on the checklist.

If you’re flying the First Flight Checklist for this aircraft after the engine overhaul or cylinder replacement, be sure to have the maintenance facility inspect the aircraft.

Use the website link at the bottom of the checklist to submit the data on your checklist to the CAP/LG Smart Sheet tool.

Constant Speed Propeller Checklist (see Attachments 3 and 4)

Purpose: To properly conduct the engine break-in following a new engine installation, overhaul, or cylinder replacement. This checklist applies to any aircraft with a variable-pitch propeller. Please record the required data fields on the checklist and input this data into the Smart Sheet form at the end.

Procedure:

Use Attachment 3 during the FIRST FLIGHT ONLY for an aircraft with a constant speed propeller. This checklist (attachment 3) is to be used when assigned by LG or PS&D following the installation of an overhauled engine or cylinders at maintenance facilities in your wing. The sortie is planned to last for TACH of 1 hour and the destination should be return to the origin airport. CAP is expecting the maintenance facility that performed the work to assist in the post flight review. So, trying to accomplish this during the business hours of the facility is to our advantage. If all parties agree the next flight would utilize Attachment 4 and the destination can be other than the origin. (e.g. return to home base)

Use Attachment 4 during all subsequent flights for the break-in period with a constant-speed propeller.

Pre-Flight Inspection additional focus – (complete normal pre-flight inspection)

Visual Inspection:

Look for oil leaks (e.g., oil on the belly or in unexpected compartments).

Take a picture of the aircraft belly for post-flight comparison.

Oil Check:

Check and record cold oil level on dipstick

Add oil to ensure the sortie starts with a full sump based off the POH.

Record both cold oil level and the amount of oil added on the checklist.

Density Altitude Planning:

Plan for an altitude that assures your ability to produce a minimum of 75% power and allows for safe traffic and obstacle separation.
In all cases do not exceed a DENSITY ALTITUDE (DA) of 7000ft DA. Anything more than 7000ft DA will PREVENT you from achieving a minimum of 75% power.

Exceptions: Turbocharged aircraft can produce higher power settings above 7000ft DA. The DA restriction is not applicable to these aircraft.

Understand that most engines cannot produce 75% power levels above 7000 ft density altitude. To achieve good engine stabilization the ability to achieve 75% power level is essential.

High elevation locations (especially during summer) should consider possible relocation of aircraft to lower altitudes during the break in process – consult CAP/LGM.

Determine and record power settings for both 65% and 75% power levels at planned density altitude.

When determining DA, POHs do not always refer to "75%" exactly in chosen altitudes when there is a choice our preference would be to choose higher power settings. (See example in Fixed Pitch Propellor section)

During Flight:

Take off and Climb Out: USE POH for all take-off settings. Once you achieve a safe obstacle clearance altitude or pattern altitude then, maintain a shallow cruise climb angle to achieve rpm requirements while avoiding overheating. (200-300 ft/min climb where obstacle clearance and noise considerations allow) Maintaining 200-300 ft/min climb rates at 75% minimum power setting allows more air to flow over cylinders and help cool cylinders. Cowl flaps OPEN.

Never exceed the maximum CHT per POH. The ideal range is 350-375F during all phases of engine break-in.

First Hour:

Cruise at appx.75% power at or below 7000 ft DA (preferably 5000 ft DA if obstacle avoidance allows).

Open cowl flaps to prevent overheating. Monitor CHT.
Record data every 20 minutes.

Second and Subsequent Hours:

Vary power between 65% and 75%, alternating every 20 minutes.

Record temperature and pressure readings.

Record the highest cylinder head temperature and cylinder position achieved in any monitored cylinder.

Issues & Descent:

If at any time readings are outside the green area for any system, return for landing and notify your AMO.

During descent, avoid sudden large power reductions to prevent extreme temperature changes. (shock cooling) Plan your descent reduce power gradually. Consider 1 inch reduction in MP every 5-7 minutes.

Close cowl flaps during descent to maintain cylinder head temperature above 300°F. if possible.

Consider using “high drag” configurations during descent to maintain higher power settings and temperatures.

Post-Flight Shutdown & Cooling:

Perform a normal shutdown and secure the aircraft.

Wait at minimum 1 hour for the engine to cool and oil to settle before checking the oil

level. Record the oil level reading on the checklist.

If you’re flying the First Flight for this aircraft after the engine overhaul or cylinder replacement, be sure to have the maintenance facility inspect the aircraft.

Use the website link at the bottom of the checklist to submit the data on your checklist to the CAP/LG Smart Sheet tool.

General Guidelines:

Flight Duration: During break-in sorties it is recommended to plan at least 2 hours but no more than 3 hours. Each checklist is built to capture a maximum of 3 hours of data per sortie.

Ground Operations: Minimize ground operations to avoid low power settings.

Weight Management: Keep the flying weight to a minimum by not carrying unnecessary crew, passengers, or equipment.

Oil Type: Use only Phillips TYPE M 20W-50 mineral oil for the break-in period. If Type M is not available, Phillips TYPE XC 20W-50 is an acceptable substitute. For Lycoming turbocharged engines, use Phillips XC ashless dispersant oil only.

Data Recording: Manually record data on the checklists during each sortie, including CHT, oil temperature, and oil consumption.

Data Submission: Enter collected data into the Smart Sheet form linked at the bottom of each checklist. The data will be reviewed by the Director of Aviation to determine if oil stabilization has occurred.

Time: CAP will use TACH time to refer to time used on checklist during engine stabilization processes. All sortie flight time totals will reflect HOBBS times. When you and your crew record data for the checklist we are expecting you to use actual time.

Like all sorties you will record HOBBS and TACH times (start and stop) in WMIRS, required by CAPR 70-1. Additionally, these stabilization sorties require reporting of data reports through the web link provided.

How do you know when you have broken the engine in?

There are several clues that the engine will give you, and one key is oil consumption, so you should really take note of what the consumption is from the start. What you will find is that the consumption will probably be quite high initially, will reduce rapidly and then plateau at a certain value.

What this value is isn't really too important - it can be anywhere in the range of 1 quart every 4 to 20 hours. An indication of stabilization is more telling. A high oil consumption rate indicates that the engine has not broken in yet (or has possibly glazed if it is over 100 hours operation).

Another key indicator is what you see from the exhaust stack. This will normally start off being black and wet (due to the high level of oil burned during the initial stages of break-in). It will then turn to black soot and finally produce a tan / grey deposit, indicating that there is little oil being burned and the mixture setting is correct.

Finally, a third indication is that of crankcase pressurization. If you fill the engine up to the maximum oil level indication and it rapidly loses the first half quart down the breather pipe, then many people just fill the engine with less oil next time. This is fine if it is an old, worn engine, but during break-in it tells you something.

The reason that the oil is being pushed down the breather is that the crankcase is being over-pressurized by exhaust gas getting past the rings. In other words, the engine is not effectively sealing itself and has not achieved a good gas seal between rings and bore – so the break-in process is not yet complete.