SUBJECT: Break-in Instructions for Titan™ Experimental Engines

PURPOSE: To establish engine break-in instructions

COMPLIANCE: When engine is placed in service following initial assembly, replacement of one or more cylinders, or overhaul


I. GENERAL INFORMATION

This Service Document provides the following information:

1. Precautions
2. Preflight Inspection
3. Operational Requirements
4. Lubrication Requirements
5. Oil Trend Monitoring and Oil Analysis
6. Run-In vs. Break-In
7. Run-In Procedures
8. Flight Check
9. Break-In Procedures
10. Cylinder Replacement

II. PRECAUTIONS

WARNING

Ensure the propeller arc is clear of personnel and obstructions before starting the engine. Do not stand or place equipment within the arc of the propeller.

CAUTION: Exceeding operating temperature limits will shorten the service life of cylinders, pistons, valves, and rings.
III. PREFLIGHT INSPECTION

- Prior to starting the engine, perform a “Preflight Inspection” of the engine, propeller, nacelle, and aircraft according to the instructions in the Airplane Flight Manual or Pilot’s Operating Handbook (AFM/POH).
- Using a suitable oil pressure pot (a clean, one-gallon capacity bladder-type pressure pot with 50 psi output pressure (not to exceed 60 psi)), ensure engine oil pressure and temperature is within normal operating range before the first start-up after the engine has been installed in the airplane. **For modified engine designs, refer to the Supplemental Type Certificate holder information and instructions.**
- Adjust the carburetor or fuel injection system to meet the manufacturer’s specifications.
- Verify magneto to engine timing is within specification.
- Check all fuel and oil lines for security and leaks. Support all hard lines to prevent fatigue. Ensure check valves are installed properly and heat protection for the fuel and oil lines are correctly installed.

  **CAUTION: Inspect and repair the cooling system (cowling, baffles, etc.). Ensure proper fit of the cooling baffles to the cylinder barrels. If an engine with tapered fin barrels is used in an installation previously having straight barrel fins, the result can be excessive air leakage. Fabricate the necessary modification to ensure all air gaps are minimized as in Figure 1.**

![Figure 1. Modified Cooling Baffles for Tapered Fin Barrels](image)

Baffle “Air Gap”

Modification to Minimize Baffle “Air Gap”
IV. OPERATIONAL REQUIREMENTS

Aircraft fuel system supply pressures may differ from those used in production test facilities. These differences in pressure will affect fuel system adjustment. Optimum performance of the fuel system directly affects engine break-in. Ensure the fuel system is properly adjusted according to the aircraft manufacturers Operator’s Manual or Aircraft Flight Manual/Pilot’s Operating Handbook, (AFM/POH).

V. LUBRICATION REQUIREMENTS

Continental Motors recommended oil grades:

- Above 40°F ambient air, sea level SAE 50 or multi-viscosity
- Below 40°F ambient air, sea level SAE 30 or multi-viscosity

WARNING

Continental Motors does not recommend use of synthetic oils or synthetic oil blends (under any circumstances) for experimental engine break-in.

<table>
<thead>
<tr>
<th>Type</th>
<th>Equivalent</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>SAE J1966 Aviation</td>
<td>Non-dispersant mineral oil for piston aircraft engines</td>
<td>First 25 hours of engine operation or until oil consumption stabilizes</td>
</tr>
<tr>
<td>MIL-C-6529 Type II Corrosion preventive mineral oil</td>
<td>Fly-away oil</td>
<td></td>
</tr>
</tbody>
</table>

NOTE: Mineral oil conforming to MIL-C-6529 Type II contains a corrosion preventive additive and must not be used for more than 25 hours or six months, whichever occurs first. If oil consumption has not stabilized in this time, perform an oil and filter change, servicing the engine with fresh, non-dispersant mineral oil conforming to SAE J1966.

Lubricating oil classified by North Atlantic Treaty Organization (NATO) or Standardization Agreement (STANAG) as interchangeable with oils qualified under SAE J1899 or SAE J1966 and assigned NATO codes O-123 or O-128 shall be considered qualified.
VI. OIL TREND MONITORING AND OIL ANALYSIS

Spectrographic oil analysis identifies concentration, in parts per million (PPM), of wear material in an oil sample collected during an oil change. Analysis begins with the first oil change sample, and continues with successive oil changes. The first oil samples establish a baseline. Subsequent samples, taken over time establish trends. These trends help determine if wear material is deviating from the baseline. Establishment of the baseline and ensuing wear trends, assumes analysis is done by the same laboratory using the same method of analysis.

Spectrographic oil analysis results will vary for reasons exclusive of engine condition. Chemical composition of engine oils vary by manufacturer. For consistent, meaningful analysis, service the engine with the appropriate grade of aviation engine oil from the same manufacturer, collect engine oil samples at regular intervals and submit the samples to the same laboratory for analysis.

Submit the oil sample to the same laboratory for analysis (unless otherwise directed). The oil analysis laboratory will provide a detailed report of the oil sample’s chemical composition for review, along with suggested corrective actions. The following laboratories provide thorough, detailed oil analysis and reporting:

- Aviation Oil Analysis
  - Aviation Laboratories
  - 3319 West Earll Drive
  - Phoenix, AZ 85017
  - 910 Maria Street
  - Kenner, LA 70062

A. Oil Sample Collection

NOTE: Collect oil samples within 30 minutes of engine shutdown.

1. Fly the aircraft for a minimum of 30 minutes, including normal cruise and maximum power settings to raise the engine oil temperature to normal operating temperature range. If you discover the engine oil needs to be serviced after flight, collect the sample prior to adding fresh engine oil.

2. Clean any dirt or debris from around the oil sump drain plug.

   NOTE: Oil sampling equipment must be clean and free of debris, foreign material, or residue to ensure sample integrity and accurate chemical analysis.

3. Use the following sample collection devices:
   a. Sampling tube and/or funnel
   b. Sample vial

4. Collect one to two ounces (30 to 60 ml) of oil from one of the following sample collection locations consistently:

   NOTE: Never take an oil sample from the bottom of the oil sump or the oil filter canister.
   a. Midstream of the oil drain flow after one-third of the oil has drained from the oil sump
   b. From the oil fill port, at least two to three inches above the bottom of the oil sump.

5. Fill the oil sample tube (or vial) 3/4 full and tighten the cap.

6. Label the oil sample vial with the date the sample was taken, the serial number of engine it was taken from, and the submitters name and company. Submit sample.
VII. RUN-IN vs. BREAK-IN

Typical engine run-in lasts no longer than two hours following engine assembly. Engine *run-in is not intended to be a complete break-in*. The objective of the run-in is to:

1. Verify the engine produces rated power.
2. Correct any oil, fuel, or induction leaks.
3. Check general operation of the fuel system.
4. Adjust initial engine oil pressure.
5. Provide initial engine prerequisites for flight check and break-in.

After run-in, the engine is released to the installer who provides the airframe, baffling, fuel settings, and all aircraft interface considerations. Break-in does not occur until the engine oil consumption has stabilized.

VIII. RUN-IN PROCEDURES

A. Run-in (Test Cell or Test Stand w/Shroud)

Regardless of technique used, the major consideration during run-in is adequate cooling of the cylinders and oil. Use appropriate test clubs and shrouds or forced air cooling. Follow these requirements to run-in an overhauled experimental engine in a test cell or when using a properly designed cooling shroud (reference Figure 2):

1. Inter-cylinder baffles must be used to ensure the cylinders are cooled on the downwind side as well as the side facing the cooling air. The shroud and baffles must be appropriate to the type engine and propeller to be used. Test club type propellers are generally shorter than flight propellers, and force the air flow close to the engine. When using a flight propeller for run-in, the cooling shroud should be constructed taller (than used on test propellers) to capture as much cooling air as possible.

![Figure 2. Example of Run-in Using a Cooling Shroud](image)

NOTE: During run-in, overheating the cylinder barrel is not always indicated by monitoring cylinder head temperature gauges (before the damage is done) because the thermocouple is located on the head rather than the barrel. Improper ring seating causes increased blow-by which heats the internal components of the engine and the oil supply. Prolonged
operation with excessive blow-by can cause premature failure of camshaft lobes. In some cases of extreme engine overheating, the pistons will expand to a diameter larger than the cylinder bore, and may result in severe scoring.

2. Forced air cooling systems used with dynamometers must provide all the cooling air and should be able to maintain cylinder head temperatures (CHT) below 400°F (204°C) at any point in the process required during the run-in test. Intercylinder baffles are normally required, and the cooling system should be capable of maintaining at least 6 inches of water static pressure differential between the cooling air intake and outlet.

3. Engine operation parameters for test cell run-in are provided in the engine manufacturer’s overhaul and service data. CMI recommends the operator follow the procedures established for the specific type of engine being tested.

**B. Run-in (Mounted Airframe Conditions)**

We recommend these procedures to run-in an overhauled experimental engine installed in an airframe:

1. Ensure all precautions contained in Section II, “PRECAUTIONS” are observed.
2. Install engine baffles and cowling to maximize cooling.
3. Instrument each cylinder to measure cylinder head temperature.
4. Orient the nose of the aircraft into the wind for ground runs.
5. Start the engine and verify oil pressure rises to within specified idle oil pressure within 30 seconds.

   **CAUTION:** If oil pressure is not observed within 30 seconds of engine start, shut down and investigate cause.

6. Operate the engine at 750 RPM for one minute, gradually increasing engine speed to 1000 RPM in three minutes. Check the magneto circuit for grounding prior to a normal shut-down. Allow the engine to cool adequately and perform a visual inspection to detect any irregularities.

   **CAUTION:** While performing ground runs, do not permit cylinder head temperatures (CHT) to exceed 400°F or oil temperature to exceed 200°F.

7. Increase to 1500 RPM. Limit engine ground runs on all cylinder types to four minutes to avoid overheating. Allow engine to cool (below 100°F CHT), and repeat short runs (less than four minutes) up to 2000 RPM to verify discrepancies are corrected.
   a. If the engine is equipped with a controllable pitch propeller, cycle the propeller allowing only a 100 RPM drop.
   b. Return to the idle range and make adjustments to the idle mixture and RPM as required on carburetor engines and to the low unmetered fuel pressure, idle RPM and mixture on fuel injected engines.
   c. Position the throttle to 1200 RPM to smooth engine operation. Perform an idle mixture rise check and adjust according to the fuel system manufacturer’s instructions.
d. Run engine up to full power for a period not to exceed 20 seconds to verify take-off power is available.
e. Shut down the engine.

8. Conduct a thorough inspection of the engine installation prior to the first flight. Correct fuel and oil leaks and reinspect all baffles and cowling. Check oil level and examine oil color to ensure blow-by has not darkened it excessively.

NOTE: Cylinder overheating can cause cylinder bore glazing and/or piston scuffing at any time during engine operation but cylinder assemblies are most susceptible to these conditions during the first 25 to 50 hours of operation. Whenever glazing and/or scuffing become severe, the only remedy is to remove the offending cylinder(s), mechanically remove the glaze, replace the piston if necessary and install a new set of piston rings.

IX. FLIGHT CHECK
The “Flight Check” ensures the engine meets operational specifications after installation in the airframe and prior to release for normal service. Preheat the engine if outside air temperature is 20°F or less.

CAUTION: Flight check is not recommended if OAT is above 90°F.

1. Conduct a normal engine start, ground run-up and take-off according to the AFM/POH.

NOTE: Keep aircraft weight to a minimum. Only required crew should be aboard the airplane for the flight check.

CAUTION: Determine if sufficient runway remains in order to reach take-off airspeed.

2. Monitor a) engine RPM, b) fuel flow and pressure (if equipped), c) oil pressure and temperature, d) cylinder head temperature (if equipped), e) exhaust gas temperature (if equipped), and f) turbine inlet temperature (if equipped) to verify the engine is operating within the parameters specified in the AFM/POH.

3. If the engine fails to reach the rated, full throttle RPM during ground operations, ascend to cruise altitude (>2000 feet above field elevation) and verify the engine achieves full throttle, full rich rated RPM at cruise altitude and operates within the limits specified in the AFM/POH; if the engine meets full power, rated RPM, proceed to step 4. If the aircraft indicated values fail to meet the published limits, repeat the Engine Operational Check and Flight Check.

WARNING
All abnormal conditions must be corrected prior to releasing the aircraft to normal operation.

4. Release the engine to normal service for Engine Break-In.
X. BREAK-IN PROCEDURES

CAUTION: High power ground operation resulting in cylinder and oil temperatures exceeding normal operating limits can be detrimental to cylinders, pistons, valves, and rings.

The recommended break-in period for Continental Motors engines is 25 hours. Adhere to the following instructions using the Engine Specifications and Operating Limits in the Operator’s Manual or the AFM/POH provided by the aircraft manufacturer.

1. Conduct a normal engine start, ground run-up and take-off according to the AFM/POH.
2. Monitor a) engine RPM, b) fuel flow and pressure (if equipped), c) oil pressure and temperature, d) cylinder head temperature (if equipped), e) exhaust gas temperature (if equipped), and f) turbine inlet temperature (if equipped) to verify the engine is operating within the parameters specified in the AFM/POH.
3. Reduce the engine speed to climb power according to the AFM/POH instructions.
4. Maintain a shallow climb attitude to achieve optimum airspeed and cooling airflow.
5. At cruise altitude:

![Figure 3. Power vs. Operating Temperatures](image)
a. Maintain level flight cruise at 75% power with best power or richer mixture for the first hour of operation.

   NOTE: Best power mixture setting is 100°-150°F (38°-66°C) rich of peak exhaust gas temperature. Adjust engine controls or aircraft attitude to ensure engine instrumentation operates within specifications.

b. For the second and subsequent hours of flight, alternate cruise power settings between 65% and 75% power with appropriate best power mixture settings.

   WARNING

   Avoid long descents at high engine RPM to prevent undesirable engine cooling. If power must be reduced for long periods, adjust the propeller to minimum governing RPM to obtain desired performance levels. If outside air temperature is extremely cold, it may be desirable to increase drag to maintain engine power without gaining excess airspeed. Do not permit cylinder head temperature to drop below 300°F (149°C).

   CAUTION: Adjust engine controls or aircraft attitude, as required, to maintain engine instrument readings within specifications.

6. Descend at low cruise power settings with careful monitoring of engine pressures and temperatures. Avoid long descents with cruise RPM and manifold pressure below 18 in. Hg. If necessary, decrease the RPM sufficiently to maintain manifold pressure. Carefully monitor engine instrumentation to maintain levels above the minimum specified cylinder head temperature and oil temperature.

7. Continue the same “BREAK-IN PROCEDURES” flight protocol until engine oil consumption stabilizes.
XI. CYLINDER REPLACEMENT

1. All replacement parts must have traceability to their origin.

2. Properly identify cylinder(s) to be replaced. Visit our website or call our Customer Service Center for further information.

3. If the removed cylinder(s) is reinstalled, determine the type of bore surface and follow the appropriate requirements described below:
   a. Through-hardened steel - impart a ring finish to the bore. New rings must be fitted to the pistons.
   b. Nickel+Carbide™ - impart a ring finish to the bores using procedures contained in the latest revision of Service Instruction SIL002, “Cylinder Bore Honing Instructions.” New rings must be fitted to the pistons.

   CAUTION: Chrome plated piston rings are prohibited in chrome plated cylinders.

4. Rings and bore surfaces must be compatible. Orange paint on the outside of the cylinder is a good visual clue that the bore has been chrome plated. See the latest revision of CMI Service Instruction SIL004, “Piston Ring Sets Applications, Fitting Instructions and Reference.”

5. Verify proper ring fit and gap accordingly.

6. Cleanliness is imperative. Debris from applying the ring finish, gapping piston rings, grinding seats, reaming guides, as well as airborne contamination, can cause severe damage to the engine.

7. Lubricate bores, pistons, and rings with a properly formulated assembly lube.

8. Install cylinder(s) according to the manufacturer’s recommended procedures.

   CAUTION: Do not use any oil containing anti-scuffing additives during break-in.

9. Do not perform a run-in on replacement cylinders with oils containing synthetic components. Synthetic oils will interfere with the ring and bore mating process which should occur as quickly as possible.
   a. Even when replacing one cylinder, the engine should be run-in according to recommendations contained in the “Section VIII, “RUN-IN PROCEDURES”
   b. Drain oil and replace with a oil conforming to SAE J1966.
   c. Install a new oil filter (or filter element).
   d. Change oil and filter at 25 hour intervals until oil consumption stabilizes.