NATIONAL TRANSPORTATION SAFETY BOARD

Office of Aviation Safety
Western Pacific Region

November, 2013

ENGINE EXAMINATION

WPR13FA289

This document contains eleven embedded photos.

A. ACCIDENT

Location:	San Luis Obispo, California
Date:	June 24, 2013
Aircraft:	Cessna P337H, N337LJ
NTSB IIC:	Eliott Simpson

B. EXAMINATION PARTICIPANTS:

Eliott Simpson
Aviation Accident Investigator
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C. SUMMARY

Examination of the recovered engines was conducted November 5 thru November 7, 2013 at the facilities of Continental Motors Inc. in Mobile, Alabama.

D. DETAILS OF THE INVESTIGATION

1.0 Engine Examination

Rear Engine

Continental Motors Inc.
Model: TSIO-360-CB (6)
Serial: 236300-R

The engine was removed from its shipping crate, and mounted on a rotating examination stand. The entire engine sustained thermal discoloration and sooting (Photo 1). The engine mounts had separated from the firewall, with the mounting stubs remaining bolted to the crankcase.

Both magnetos remained attached to the crankcase; the spark plug leads were thermally damaged and continuous to the spark plugs. The oil filter remained attached to its adapter, which had become melted away from the crankcase pad. The oil drain plug was separated from the sump, with its threaded portion remaining within the sump boss. The crankshaft propeller flange had separated from the crankshaft at the front seal; the separation features where conical in shape.

The propeller governor remained attached to the forward crankcase, with its control linkages continuous through to the firewall. The propeller synchronization motor and gears remained attached. The governor unit was removed, and the input shaft rotated smoothly by hand, and brown-colored oil flowed from the passages; the screen was free of debris. The control arm moved freely. Disassembly revealed the pump gears, fly weight and gear to be intact.

The alternator remained attached to the crankcase, but had sustained thermal damage, melting its outer casing. The air conditioner, vacuum pump, and starter motor assembly remained attached to the aft crankcase.

The engine driven fuel pump remained attached to the forward crankcase, appeared externally undamaged, and was coated in black soot; all fuel lines were firmly attached at their fittings on the pump. The mixture control arm had become bent 90 degrees, with its control cable and eyebolt remaining attached. The control cable was continuous from the linkage to the firewall where it was cut by recovery personnel.

All upper ancillary components, including the fuel manifold valve, induction manifold risers, and fuel metering unit, were intact and attached. All lines to the fuel injection nozzles were intact with their fittings tight.

All cylinders and pistons were removed for examination. The piston faces, intake valve heads, and the dome areas within each chamber were covered in light grey deposits, and coated in black soot. Each exhaust valve exhibited symmetrical coloration of the valve head. No mechanical damage was noted. All piston pins were free of scratches or indentations, and all piston rings moved freely within their skirts. The rocker areas were wet with oil, and free of distress. All pushrods were straight. The spark plug electrodes were free of mechanical damage, coated in black soot, and exhibited wear signatures to their electrodes consistent with "normal" operation when compared to the Champion AV-27 Check-A-Plug chart (Photo 4).

The crankcase was disassembled, and the magneto drive, crankshaft, camshaft cluster, starter, propeller shaft, and quill shaft gears were intact, undamaged, and coated in brown-colored oil.

The oil sump contained residual quantities of brown-colored oil. The camshaft and followers were wet with oil, and were removed for examination. All bearing and lifting surfaces were intact and smooth. All hydraulic lifter contact surfaces were smooth, oil wet, and free of indications of spalling to their contact surfaces. The oil pump gears as well as the pump cavity were intact and free of scoring.

Turbocharger

The turbocharger assembly had become separated from the exhaust manifold, with the engine exhaust outlet exhibiting crush damage. The internal surfaces of the exhaust pipes exhibited light grey deposits. The wastegate actuator was broken away from the wastegate body. The turbocharger housing was subsequently disassembled.

The inlet shroud was removed and the compressor turbine examined; the turbine was intact, and rotated freely by hand. The blades were intact with midspan wrinkling observed to half of the blades. The exhaust turbine appeared undamaged, and remained connected to the compressor turbine. The scavenge check valve was thermally damaged but remained intact, and the flapper valve moved freely although the spring tension was no longer present. The boost valve manifold was intact, with the valve in place within the duct. The boost actuator remained connected to the valves control arm.

Fuel Pump

Part Number: 649368-1
Serial Number: B01EA255R

The engine driven fuel pump sustained thermal damage and sooting and was removed for examination; the fuel lines were capped, and the unit was externally cleaned with solvent. The input shaft coupling remained attached and was undamaged, and the shaft could be rotated by hand with slight but smooth resistance felt. The unit was installed on a fuel injection test stand and tested in accordance with CMI fuel pump test procedures -20 (Photo 2). Fluid was observed to leak from the low-end adjustment seal when fluid was applied. The unit passed the flow/pressure test at 600 RPM, with a flow rate of 8.85 lbs/hr at a pressure of 7.2 psig (nominal 8-9 lbs/hr, 6.5 -7.0 psig).

At a speed of 2,800 RPM, the fuel pump was tested at a flow rate of 200.35 lbs/hr, and failed due to a resultant pressure indication of 10 psig. (Nominal: 15-17 psig at 200 lbs/hr). The unit was tested again at 600 RPM with the same result as the first 600 RPM test.

Turbo deck pressure of 39.39 in/hg was applied, and air was heard and felt to leak from the aneroid case O-ring seal. At 2,800 RPM the unit again failed, with 201.88 lbs/hr resulting in a pressure of 14.1 psig. (Nominal 36.0-36.5 psig at 199-201 lbs/hr with top deck pressure of 39 in/Hg).

The unit was disassembled; the diaphragm seal was intact and stiff, sustaining thermal damage which resulted in globules coalescing on its outer surface. The mixture shaft cavity exhibited radial score marks to the inner surface. The rotor and vanes were intact. The aneroid was removed, and its solder joints appeared melted. The aneroid appeared to have expanded about 3/8 inch beyond its nominal size (Photo 3). The aneroid was dipped in water and appeared free of obvious leaks. When installed in a vacuum chamber, pressure was applied (56 PSI), and the unit was unable to maintain pressure.

Fuel Metering Unit

Part Number: 640563-12
Serial Number: A01EA238R

The fuel metering unit was removed for examination. The service cap remained attached, and the inlet and outlet fuel lines were attached and in place. The unit was attached to a fuel pump on a test stand and flowed with fuel. Fuel flowed through the outlet at the open throttle setting, and the fuel flow reduced appropriately when the throttle was closed. The unit was tested for fuel flow versus pressure at varying throttle angles utilizing the throttle body test stand, with the following results:

TARGET ANGLE (°)	MEASURED ANGLE (°)	TARGET PRESSURE (PSI)	MEASURED PRESSURE (PSI)	MEASURED TEMPERATURE (°F)	MIN FUEL FLOW (LBS/H)	MAX FUEL FLOW (LBS/H)	MEASURED FUEL FLOW (LBS/H)
2.000	2.000	7.700	7.634	75.344	7.000	7.400	24.388
20.000	20.000	7.700	7.666	75.386	49.000	58.800	64.518
40.000	40.000	7.700	7.683	75.388	78.000	83.900	94.116
60.000	60.000	7.700	7.691	75.417	100.000	107.500	108.456
74.000	**74.000**	**7.700**	**7.680**	**75.459**	**105.000**	**110.300**	**108.770**

The test was repeated with similar failure results.

Fuel Manifold Valve

Part Number: 641032 13A5
Serial Number: B018801C

The manifold valve was connected to the fuel pump, and fuel pressure was applied. Fuel flowed from the nozzles. The unit was then installed on manifold valve test cell. A calibration test was performed, and the unit failed just beyond the upper limits:

FLOW (PPH)	PRESSURE (PSIG)	LOW LIMIT	HIGH LIMIT	TEST STATUS
10	4.043	3.410	4.210	REF
50	6.376	5.550	6.350	FAIL
100	11.448	10.790	11.190	FAIL
150	19.409	18.620	19.420	PASS

The fuel manifold valve and associated injector and lines were removed and disassembled. The valve assembly diaphragm was pliable and free of cracks, and the fuel screen was free of debris.

Magnetos

The outer surface of the left magneto was charred, the plug and points cap was subsequently removed, and points examined. The metallic portions of the points were in place, with both of its attachment screws tight. The case was opened for examination, and the distributor gear had melted; the metal drive gear remained in place with all of its teeth intact; the coil remained intact. All electrical wires were intact, with their insulation burnt away.

The outer surface of the right magneto was charred, the plug cap was melted, and the points cap was thermally deformed. The points cap and plug cap remnants were subsequently removed, and points examined. The plug terminations were charred and crumbled upon removal of the cap. The metallic portion of the timing and shower of sparks points were in place, with both of their attachment screws tight. The case was opened for examination, and the distributor gear had melted; the metal drive gear remained in place with all of its teeth intact; the coil had melted. All electrical wires were intact, with the insulation burnt away.

Front Engine

Continental Motors Inc.
Model: TSIO-360-C (5)
Serial: 230775-R

The engine was removed from its shipping crate, and mounted on a rotating examination stand (Photo 5). The engine had separated from the firewall. The front left engine mount remained attached to the crankcase; the remaining three mounts had separated with their stubs still bolted to the crankcase. The oil sump sustained cracks to its lower right side, and no oil was present. The oil drain plug remained in place. The oil filter remained attached to its adapter, which was broken away from the crankcase pad.

The right magneto remained attached to the crankcase; the left magneto had broken away from its pad, with both mounting lugs still firmly attached to the crankcase (Photo 6). All spark plug leads, with the exception of the lower cylinder number 2, were continuous to the spark plugs.

The propeller governor remained attached to the forward crankcase; its control linkage was continuous through the forward baffling and had separated at the flex cable termination. The governor control arm spring had come away from its pinion, and the arm rotated freely. The screen was free of debris.

The alternator remained attached to the crankcase, but had sustained impact damage, separating its outer casing. The vacuum pump and starter motor assembly remained attached to the aft crankcase.

All upper ancillary components, including the fuel manifold valve, induction manifold risers, and fuel metering unit, were intact and attached. All lines to the fuel injection nozzles were intact with their fittings tight. The throttle linkage remained attached to the throttle body, and had separated at the flex cable termination.

The spark plug electrodes were free of mechanical damage, coated in grey deposits, and exhibited wear signatures to their electrodes consistent with "normal" operation when compared to the Champion AV-27 Check-A-Plug chart.

Turbocharger

The turbocharger assembly had become separated from the exhaust manifold, with the engine exhaust outlet exhibiting crush damage. The internal surfaces of the exhaust pipes exhibited light grey deposits. The wastegate actuator assembly remained partially attached to the exhaust manifold, with its linkage to the wastegate valve intact. The compressor impellor and associated shroud had separated from the exhaust turbine shroud. Six of the impellor vanes were bent opposite the direction of rotation, and the entire impellor could be rotated by hand. The exhaust turbine had become impinged against the shroud, but could be rotated utilizing a wrench on the center nut.

Fuel Pump

Part Number: 646758-1
Serial Number: B01881DBR

The engine driven fuel pump remained attached to the forward crankcase, and appeared externally undamaged, with all fuel lines and the deck reference line firmly attached at their fittings on the pump; the vapor return line had broken off at the fitting, with its threaded portion remaining inside the housing. The mixture control arm cable and eyebolt remained attached. The control cable was continuous from the linkage to the firewall where it was cut by recovery personnel. The fuel metering unit and wastegate controller interconnect pushrods were intact. The input shaft coupling remained attached and was undamaged. Rotation of the pump by hand resulted in intermittently stiff movement. The pump was opened, exposing the rotor and vanes. Brown rust was present on the vane tips, and half of the inner pump cavity surface. The rust was presumed to be caused by water ingestion during the post-accident firefighting effort. The rust was removed with an abrasive pad, and the pump was reassembled.

The unit was installed on a fuel injection test stand and tested in accordance with CMI fuel pump test procedures (-20). The pump passed all test except the 2,800 RPM flow rate test, where it indicated a pressure of 14.4 psig and 33.9 psig at ambient pressure and top deck pressure of 39.39 in/hg respectively. The values were just below nominal, and not deemed to be unusual (Nominal: 15-17 psig at 199-201 lbs/hr and 36.0-36.5 psig at 199-201 lbs/hr with top deck pressure of 39 in/Hg).

The left magneto was installed on a test stand and operated at speeds varying between 500 and 2,100 RPM. All leads produced a spark in firing order, and the impulse coupling triggered appropriately. The left mounting clip for the right magneto was temporarily removed, in an effort to determine if the magneto had moved during the accident sequence. The engine pad, magneto lug, and mounting clip were free of damage, and the magneto case was intact (Photo 9, 10).

The ignition timing for the right magneto was tested in place on the engine utilizing a magneto synchronizer. The test revealed that the magneto points opened at 1 degree after top dead center (ATDC), instead of the nominal 20 degrees before top dead center (BTDC) (Photo 7, 8).

Engine Test Run

The following components sustained varying degrees of impact damage and were replaced in preparation for an engine run:

Cylinder number one; left and right magneto cable harnesses; the entire exhaust assembly, including all manifolds and pipes, and turbocharger (slave installed); starter motor; oil filter and adapter.

The turbocharger wastegate assembly was replaced with a fixed type, and the wastegate actuator control remained in place but was not utilized. The governor was removed, and fixed pitch ground adjustable propeller installed. The cracks in the oil sump were plugged with epoxy glue.

A pre-engine run cylinder leakage test was performed in accordance with the latest revision of CMI Service Bulletin SB03-3 on each cylinder with the engine cold. The results were as follows:

Cylinder #1: 69/80 PSI (rings)	Cylinder #2: 15/80 PSI (rings)
Cylinder #3: 69/80 PSI (rings)	Cylinder #4: 12/80 PSI (rings)
Cylinder #5: 72/80 PSI (rings)	Cylinder #6: 55/80 PSI (rings)

The engine was installed in a test cell, and an engine run was performed with the right magneto remaining in its as-found position of 1 degree ATDC. The left magneto was set to the same timing position. The engine started after two attempts, and was run at 1,000 RPM for five minutes to its operating temperature. The throttle was then advanced full open, and the engine speed accelerated to a maximum of 1,850 RPM with an indicated manifold pressure (MP) of 38.5 inHg. A magneto check was then performed, with a speed drop of 200 RPM observed for each magneto.

The left magneto was then set to the correct ignition timing of 20 degrees BTDC, and another engine run was performed. The engine started immediately and the throttle was advanced 2/3 of its travel, resulting in an engine speed of 1,860 RPM, with an indicated MP of 37.5 inHg. A magneto check was performed at 1,800 RPM a drop of 20 RPM was observed when the left magneto was selected, and a drop of 240 RPM with the selection of the right magneto. The test was then stopped in an effort to prevent an overboost condition.

A final series of four engine runs were performed with both magnetos set to 20 degrees BTDC. The propeller pitch was increased progressively during each run to prevent an overboost condition. For the last test, the engine reached a speed of 2,775 RPM at 36.5 inHg MP; during this test the engine speed was cycled through its entire range, and both accelerated and decelerated smoothly throughout.

A post engine test cylinder leakage test was performed in accordance with the latest revision of CMI Service Bulletin SB03-3 on each cylinder with the engine hot. The results were as follows:

Master orifice reading – 39 PSI

Cylinder #1 - 75/80 PSI (rings)	Cylinder #2 - 71/80 PSI (rings)
Cylinder #3 - 67/80 PSI (rings)	Cylinder #4 - 70/80 PSI (rings)
Cylinder #5 - 74/80 PSI (rings)	Cylinder #6 - 73/80 PSI (rings)

Magnetos - Follow Up

A subsequent examination of the right magneto was performed the following week by an NTSB Investigator. The magneto was installed on a test stand and operated at speeds varying between 500 and 2,100 RPM. All leads produced a spark in firing order. The unit was disassembled and appeared undamaged and correctly timed. The only anomaly noted was grease on the edge of the internal cap prongs for cylinder 3 and 6. No grease was on the contact surface.

2.0 Examination Photos

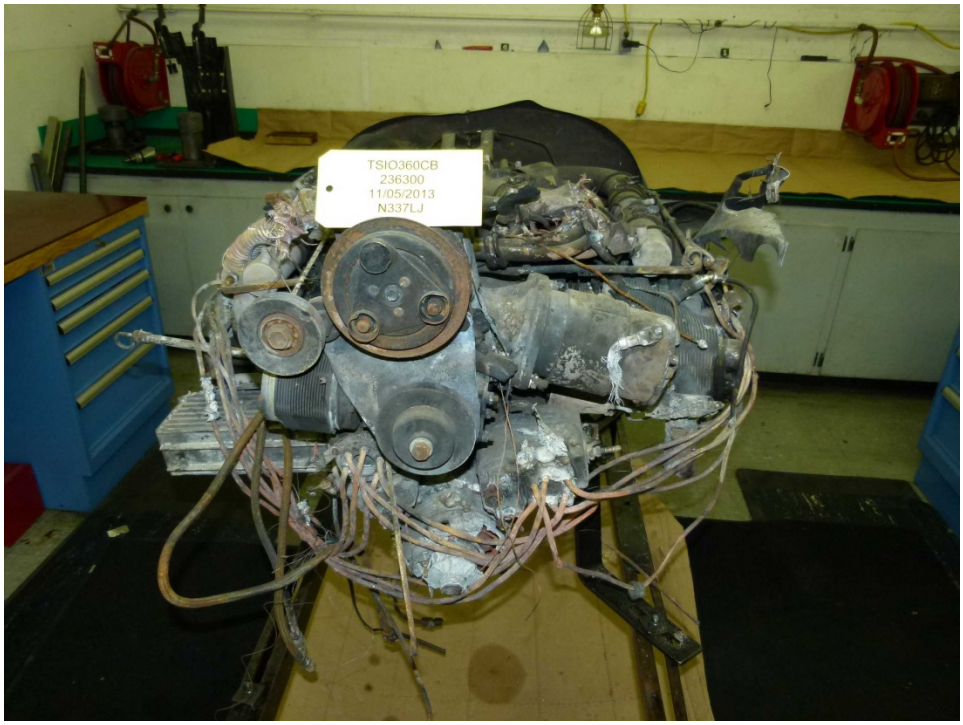

Photo 1 - Rear Engine on Examination Stand

Photo 2 - Rear Engine Fuel Pump

Photo 3 - Rears Engine Aneroid Bellows (Exemplar Above)

Photo 4 - Rear Engine Spark Plugs

Photo 5 - Front Engine on Test Stand

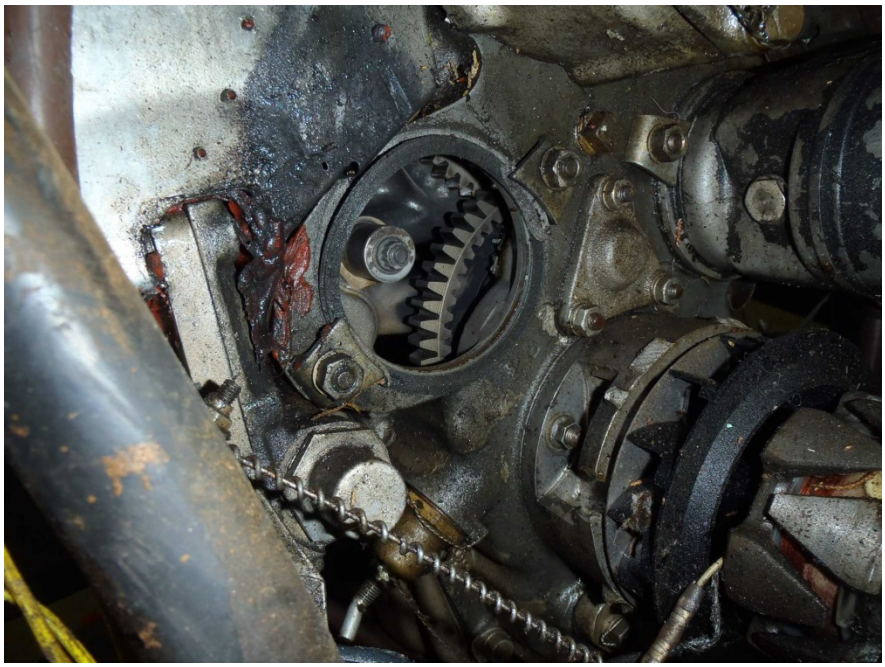

Photo 6 - Front Engine - Left Magneto Pad

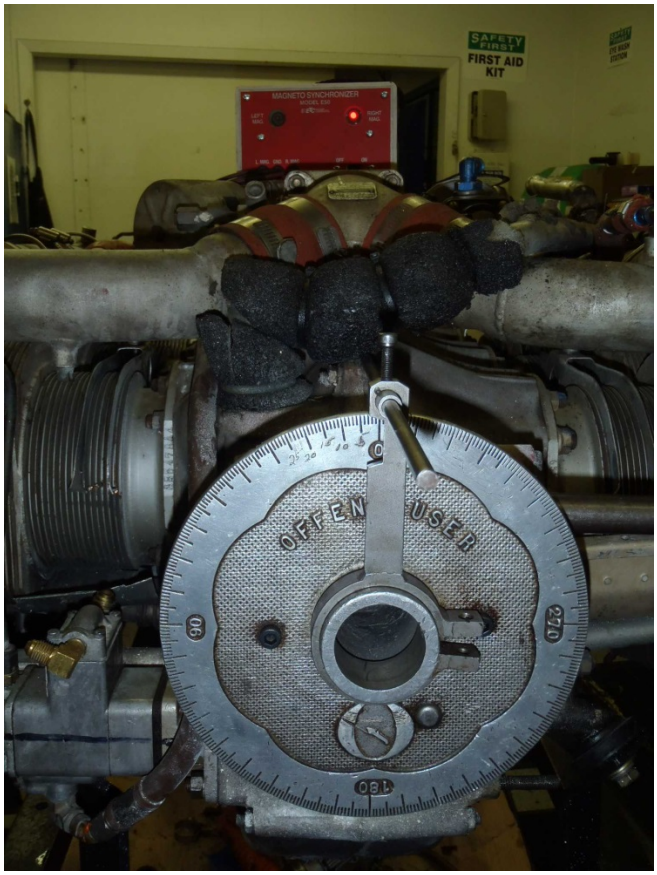

Photo 7 - Front Engine Right Magneto Timing

Photo 8 - Front Engine - Right Magneto Timing Inspection Hole

Photo 9 - Front Engine - Right Magneto

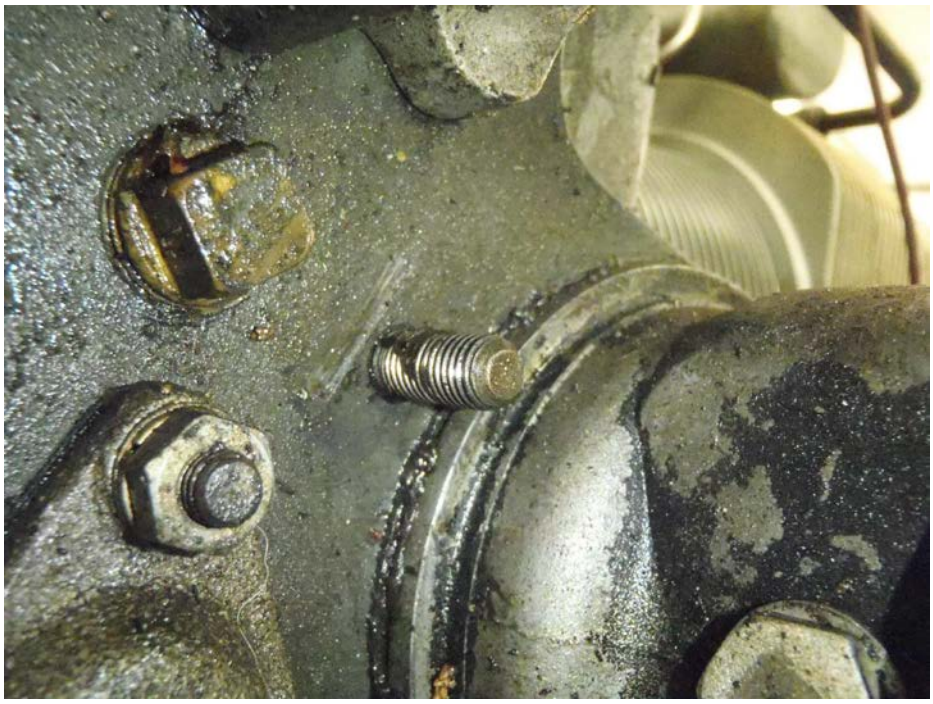

Photo 10 - Front Engine - Right Magneto with Left Clip Removed

Photo 11 - Front Engine Operating In Test Cell

Submitted: Eliott Simpson