Memorandum

U.S. Department
of Transportation

Federal Aviation Administration

Subject: ACTION: Request for Review and Concurrence with Equivalent Level of Safety (ELOS), for the Cessna C182E,F,G,H,J,K,L,M,N and P Airplane to 14 CFR part 23, § 23.991(a)(1) and § 23.991(b), Mechanical Fuel Pump Requirements Equivalent Level Of Safety. ACE-03-06

Date: February 19, 2004

From: Manager, Special Certification Branch, ASW-190

Reply to Attn. of: Richard Karanian
817-222-5195

To: Manager, Small Airplane Directorate, ACE-100

The Ft. Worth Aircraft Certification Office is currently processing an application for a Supplemental Type Certificate to incorporate a belt driven supercharger on a Teledyne Continental Motors O-470-L,-R and –S installed in the Cessna C182E,F,G,H,J,K,L,M,N and P. A P-1, Stage 3 Issue Paper has been submitted to the Small Airplane Directorate. The purpose of this memorandum is to request your concurrence to an equivalent level of safety finding for installation of dual electric fuel pumps in lieu of an engine driven fuel pump and separately power emergency pump as required by 14 CFR, part 23, § 23.991(a)(1) and § 23.991(b).

Background:

This certification effort is a Supplemental Type Certificate to install a belt-driven Vortech V-1S centrifugal impeller supercharger in Teledyne Continental Motors (TCM) O-470-L, -R, and -S engines (Ref. TCDS E-273 and FAA Project No. ST7371SC-E) in which will be installed on Cessna Models 182E, F, G, H, J, K, L, M, N and P series aircraft (FAA Ref. Type Certificate Data Sheet (TCDS) 3A13 and Project No. ST7370SC-A). Approval is being administered by CenTex Aerospace Inc., located in Waco, TX. This certification effort has no intention of taking advantage of the improved aircraft performance by not revising the AFM.

With the supercharger installation, the engine now becomes normalized producing sea level, take-off power to approximately 7,000 feet MSL. The supercharger produces a pressure ratio of 1.2 (Manifold vs. Ambient) at engine RPMs of 2600 RPM, therefore, at sea level, 6 inches of boost (3 PSI) can be obtained, and at FL 180, 3 inches (1.5 PSI) of boost can obtained. The supercharger impeller speed is a function of engine RPM and does not increase its speed with altitude like a turbocharger. These boosted pressures also include line losses from the supercharger through the carburetor. Also, the engine will be pilot limited to 28 inHG MAP (red-line), therefore, at sea level very little boost is used.

The Teledyne Continental O-470 engine installed in Cessna 182 aircraft was designed with a gravity fuel flow system. This system was ample enough to supply fuel to the carburetor, which only required a minimum of 0.5 PSIG and thus not requiring mechanical or emergency fuel pumps. As the fuel level moves up and down in the float bowl of the carburetor, air from the induction system moves in and out of the float chamber through a vent to the induction system. When the induction system becomes pressurized from the supercharger so does the air in the float chamber. Therefore, greater fuel pressures are now required to overcome the boosted pressures in the carburetor from the installed supercharger. When the engine is operated above approximately 1700 RPM, the air in the float chamber of the carburetor becomes pressurized by the supercharger to a point equal to the gravity feed fuel pressure. At this point gravity feed fuel pressure is not sufficient to supply the engine.

A mechanical pump drive pad does exist on the engine, but design limitations (i.e. lack of engine compartment space, physical interference with the alternator, procurement of mechanical pumps, in which OEM pumps are no longer manufactured, adaptors, internal fuel pump to engine cams, etc.) drove the applicant to design the current installation. Therefore, two electrically driven fuel pumps have been installed, one of which is standby, to overcome these increased boosted air pressures from the supercharger to the carburetor. The electrical fuel pumps are Weldon model A8164-A pumps, and they are cammed vane pumps with internal pressure relief valves. The relief valve pressure is 6.5 PSIG. Each fuel pump will raise the fuel pressure to a maximum of 6.5 PSI. The maximum boosted induction pressure is 3 PSI (or 6 inHG) at sea level and 1.5 PSIG (or 3 inHG) at FL180. This provides a net fuel pressure at the carburetor of 3.5 PSI at sea level and 5 PSIG at FL180. The originally installed MA4-5 carburetor is made to operate between 15 inches of fuel (0.375 PSI) and 6.0 PSI.

Each fuel pump has its own electrical circuit using Klixon circuit breakers and Cessna cockpit installed switches. A non-electrical wet fuel pressure gauge, marked accordingly with a normal, caution and warning ranges is installed in the upper right corner of the panel near the engine gauges, in an existing cutout to monitoring fuel pressure up stream of the carburetor.

The Cessna 182, as certified, is equipped with a single bus electrical system with a single alternator and a single battery.

<u>Applicable Regulations:</u>

The requirements of 14 CFR Part 23 § 23.991, Fuel Pumps, are as follows:

> (a) *Main pumps.* For main pumps, the following apply:
> (1) For reciprocating engine installations having fuel pumps to supply fuel to the engine, at least one pump for each engine must be directly driven by the engine and must meet Sec. 23.955. This pump is a main pump.
> (2) For turbine engine installations, each fuel pump required for proper engine operation, or required to meet the fuel system requirements of this subpart (other than those in paragraph (b) of this section), is a main pump. In addition--
> (i) There must be at least one main pump for each turbine engine:
> (ii) The power supply for the main pump for each engine must be independent of the power supply for each main pump for any other engine; and
> (iii) For each main pump, provision must be made to allow the bypass of each positive displacement fuel pump other than a fuel injection pump approved as part of the engine.
> (b) *Emergency pumps.* There must be an emergency pump immediately available to supply fuel to the engine if any main pump (other than a fuel injection pump approved as part of the engine) fails. The power supply for each emergency pump must be independent of the power supply for each corresponding main pump.
> (c) *Warning means.* If both the [main] pump and emergency pump operate continuously, there must be a means to indicate to the appropriate flight crewmembers a malfunction of either pump.
> (d) Operation of any fuel pump may not affect engine operation so as to create a hazard, regardless of the engine power or thrust setting or the functional status of any other fuel pump.

Compensating Features:

The applicant does not directly comply with the requirements of § 23.991(a)(1) due to the lack of an engine driven fuel pump. The applicants proposed solution to the requirements of 14 CFR Part 23 § 23.991(a)(1) is as follows:

1. Dual electrical fuel pumps are provided in case of a mechanical failure of any one pump. Only one pump is necessary to operate the engine for all power settings during normally boosted operations. Either installed pump may be used as the main fuel pump, with the other pump functioning as the emergency fuel pump. At power settings above the ability of gravity fuel to supply the engine, the loss of the operating pump results only in a rough running engine. The fuel pressure gauge will indicate 1.5 psig or less (red arc). Switching on the emergency fuel pump will restore fuel pressure and smooth engine operation will return in 3 seconds or less.

The applicant does not directly comply with the requirements of § 23.991(b) due to the lack of independent power supply for the emergency fuel pump. The applicants proposed solution to the requirements of 14 CFR Part 23 § 23.991(b) are as follows:

1. Main Fuel Pump Failure:
   a. The aircraft is equipped with an emergency fuel pump that will restore fuel pressure and smooth engine operation will return in 3 seconds or less.
   b. A calibrated, wet line type, fuel pressure gage is installed to indicate normal, cautionary, and warning fuel pressures.
      i. A green arc is provided to show the normal fuel pressure range between 4.0 and 7.0 psig that is obtained for any single pump operation.
      ii. A yellow arc is provided to show the cautionary fuel pressure range during any faulty single pump operation.
      iii. A redline is provided to show the warning fuel pressure range when the fuel pressure is not sufficient to overcome the boost provided by the supercharger.
   c. A low fuel pressure warning light, "FUEL PRES LOW", will be installed to warn the pilot that the fuel pressure is 1.5 psig or less (red arc).
2. Alternator Failure on a Single Bus System:
   a. The pilot will have the indication of a discharging battery from the originally installed ammeter.
   b. The pilot will be alerted to the alternator failure by the newly installed cockpit red "ALT INOP" light.
   c. The battery capacity of the electrical system is sufficient to power the fuel pumps in excess of 30 minutes. The fuel pumps are not required for continued safe flight due to the boost cutoff system described below; therefore, no credit for compliance with 14 CR 23.1353(h) is being sought.
3. Complete Electrical Failure:
   a. The supercharger boost levels can be reduced by actuating the newly installed, pilot-controlled, mechanical, boost cutoff control and valve.
      i. The boost cutoff valve is a butterfly valve installed in the supercharger duct between the supercharger and the carburetor. In the event of a dual fuel pump failure, this valve can be used to regulate induction airflow to the carburetor in the same fashion the throttle valve regulates carburetor airflow.
      ii. During normal (boosted) operations, the boost cut-off valve is wide-open, or parallel, to the duct airflow in the supercharger duct. When the boost cut-off control is pulled out to the full positive hard stop position and left untouched, the boost cutoff butterfly valve

will rotate to a setting of 50° from the wide open position, reducing the airflow downstream from the valve to the carburetor.

iii. Fully pulling the boost cut-off control reduces the air delivery to the carburetor to approximately normally aspirated economy power setting levels at all altitudes, which will allow continued safe flight operations (See Figure 1).

iv. The reduction in air pressure to the carburetor will allow gravity fuel feed to the carburetor for continued safe flight engine operation.

v. Using the boost cut-off in this manner will restore smooth engine operation in approximately 1.5 seconds.

vi. To obtain higher power settings, the boost cut-off control can be pushed in or modulated with full throttle to valve angles less than full cutoff thus increasing the engine power similar to maximum normally aspirated engine power levels. Power settings will be limited to manifold pressures equivalent to ambient pressure minus 2 inHG (See Figure 1) for normally aspirated, normally boosted, full boost cutoff, and modulated boost cutoff engine power levels.

vii. In the event of a boost cutoff cable failure, a set screw in the supercharger duct prevents the boost cut-off butterfly valve from rotating past the full open position (parallel to the duct airflow).

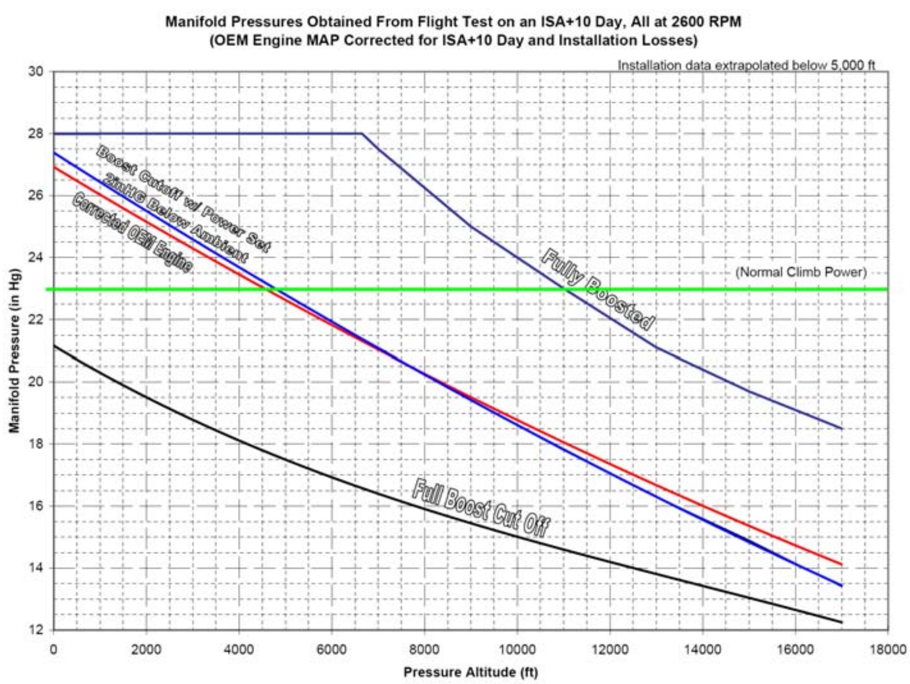

Figure 1

b. A calibrated, wet line type, fuel pressure gage is installed to indicate normal, cautionary, and warning fuel pressures:

i. A green arc is provided to show the normal fuel pressure range between 4.0 and 7.0 psig that is obtained for any single pump operation.

ii. A yellow arc is provided to show the cautionary fuel pressure range during any faulty single pump operation.

iii. A redline is provided to show the warning fuel pressure range when the fuel pressure is not sufficient to overcome the boost provided by the supercharger.

The applicants will also include the following to meet the requirements of 14 CFR Part 23 § 23.991(a)(1) and § 23.991(b):

1. The AFMS will be revised to handle failures for single pump failures, alternator failures, and dual electrical pump failures. These procedures will assist the pilot in maintaining continued safe flight following alternator failure and subsequent battery depletion, and recommend to the pilot to land as soon as practical.
2. A table in the AFMS and a cockpit-installed placard will assist the pilot to obtain higher power settings, in the event of complete electrical failure, for takeoff, climbs and balked landings. These procedures will be demonstrated by certification flight test.
3. As part of the AFMS, pre-flight checks for each fuel pump, "alternator inop" light, and the boost cutoff control and valve will be manually tested for satisfactory operation. If any of these systems are inoperative then flight cannot be commenced.

Applicant Position:

Based upon the background and the discussions provided for the design mitigations, an equivalent level of safety for the intent of 14 CFR 23.991(a)(1) and 23.991(b) has been provided for these regulations with the installation of the dual low amp draw electrical fuel pumps, the boost cutoff control valve, the fuel pressure gage, the "ALT INOP" light, the "FUEL PRES LOW" light and the AFM supplement.

Recommendation:

We concur that the dual electric fuel pumps provides an equivalent level of safety as envisioned in the regulations and therefore meet the requirements of §§ 23.991(a)(1) and §§ 23.991(b).

S. Frances Cox

Concurred by:

Barry Ballenger for — Feb. 25, 2004
Manager, Standards Staff, ACE-110 — Date

James E. Jackson for — Feb. 25, 2004
Manager, Small Airplane Directorate
Aircraft Certification Service, ACE-100 — Date