U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: INSTALLATION OF FUEL FLOWMETERS IN SMALL AIRPLANES WITH CONTINUOUS-FLOW, FUEL-INJECTION, RECIPROCATING ENGINES

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Initiated by: ACE-100

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Change:

1. PURPOSE. This Advisory Circular (AC) sets forth acceptable means, but not the only means, of showing compliance with Part 3 of the Civil Air Regulations (CAR) and Part 23 of the Federal Aviation Regulations (FAR) applicable to the installation of fuel flowmeters/fuel totalizers in small airplanes with continuous-flow, fuel-injection, reciprocating engines. This material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. RELATED REGULATIONS. These acceptable means of compliance refer to certain provisions of Part 23 of the FAR and the corresponding provisions of the former Part 3 of the CAR in the case of airplanes for which those regulations are applicable. Listed below are the applicable FAR sections with the related CAR sections shown in parentheses:

	FAR Section
a.	23.773 (3.382)
b.	23.955 (3.433)
c.	23.961 (3.438)
d.	23.991 (3.449)
e.	23.993 (3.550)
f.	23.1183 (3.638)
g.	23.1191 (3.624)
h.	23.1305 (3.655)
i.	23.1337 (3.673)
j.	23.1529
k.	23.1541 (3.755)
l.	23.1543 (3.756)
m.	23.1549 (3.759)

3. BACKGROUND.

a. Recently there has been a trend toward replacing fuel pressure indicators and analog reading fuel flowmeters with digital fuel flowmeters/fuel totalizers. New developments in microprocessor technology have resulted in digital fuel flow computer systems that are economical, accurate, and that provide data for improved fuel management. These digital fuel flow computer systems also have features for displaying total fuel consumed, total fuel remaining, and time remaining; however, the accuracy of these readings are dependent upon the initial fuel supply entered into the fuel computer. The precise digital readings that are displayed to the nearest tenth of a gallon could give the pilot a false sense of accuracy and security, especially the readings for total fuel remaining and time remaining.

b. Digital fuel flowmeters are not a required powerplant instrument. They are optional equipment and should not be considered replacements for fuel quantity or fuel pressure indicators. Different interpretations of the FAR have caused conflict and lack of national standardization on installation of fuel pressure indicators and fuel flowmeters/fuel totalizers in small airplanes that have continuous-flow, fuel-injection systems. Inquiries from members of the aviation community and manufacturers have indicated a need for information concerning approval and installation of digital fuel flowmeters/fuel totalizers. The location of the fuel flow transducer in the fuel system is critical for measuring the total fuel flow consumed by the engine and maintaining engine performance. Each type of installation has an impact on the operation of the fuel system and needs to be evaluated and approved.

4. DISCUSSION.

a. Fuel Pressure and Fuel Quantity Indicator.

(1) A fuel pressure indicator is required for pump-fed engines in accordance with section 23.1305(g), and it is intended to monitor unmetered fuel pressure at the inlet to the injector and advise the pilot of a fuel pressure deficiency. Many small airplanes with reciprocating, continuous-flow, fuel-injection engines are equipped with fuel pressure indicators that actually measure metered fuel pressure. Metered fuel pressure in a fuel-injection system also relates to fuel flow, and can provide a satisfactory method for displaying fuel flow. However, replacing the metered fuel pressure indicators with fuel flowmeters could cause an unsafe condition by failing to provide critical fuel pressure information to the pilot that is especially important during the takeoff phase of the flight. Fuel flowmeters are not required powerplant instruments for reciprocating engines to meet airworthiness standards of Part 3 of the CAR or Part 23 of the FAR.

(2) Digital fuel flow computer systems have a fuel flow transducer that directly measures the amount of fuel being fed to the engine. The fuel flow transducer may be a small paddle wheel, an impeller, or spring-loaded movable vanes. Digital displays with a fuel computer also permit these instruments to display total fuel consumed, total fuel remaining, and time remaining at the present fuel flow rate for fuel management. Overall accuracy for fuel remaining and time remaining readings depends on the transducer processing unit and display, but the largest possible error is the initial fuel supply which is entered by the pilot at the start of each flight. Errors in the initial fuel supply may be caused by uneven ramp, unusual loading, volume changes of the fuel due to temperature variations, malfunctions in the fuel system such as leaks, siphoning actions, collapsed bladders, and other factors; therefore, total fuel remaining should be verified with the fuel quantity indicator. In accordance with section 23.1337b(1), fuel quantity indicators are required to be calibrated to read "zero" during level flight when the quantity of fuel remaining in the tank is equal to the unusable fuel supply. For this reason, fuel quantity indicators should be used as the primary fuel-remaining instruments. Fuel quantity indicators that are inaccurate should be periodically calibrated and/or repaired if necessary to ensure reliable readings.

b. Fuel-Injection Systems. Fuel-injection systems have been designed for many types of reciprocating engines, and vary in details of construction, arrangement, and operation. Only continuous-flow, fuel-injection systems for reciprocating engines will be discussed in either the speed-sensing pressure pump or constant-pressure pump categories.

(1) Fuel-Injection System with Integral Speed-Sensing Pressure Pump.

(i) A fuel-injection system with an integral speed-sensing pressure pump delivers fuel at a pressure proportional to engine speed, and the pump is approved as part of the engine type design during the engine certification process. The fuel injection system has fuel lift capability that enables the system to function with a negative inlet pressure within specific limits as indicated by the engine type data sheet. An emergency fuel pump is not required when the fuel injection pump is approved as part of the engine in accordance with section 23.991(b). The airframe manufacturers may provide an auxiliary fuel pump located upstream of the fuel-injector pump for priming the engine and for suppressing fuel vapors. This auxiliary fuel pump can provide some fuel flow during emergency operations, but may not sustain engine operation at full power in the event the engine-driven, fuel-injector pump fails; therefore, it is not considered an emergency fuel pump.

(ii) If the fuel system in the airplane can meet the fuel flow requirements of section 23.955(c) at the minimum allowable inlet pressure limits without the need of an external pump, a fuel pressure indicator is not required. Nonetheless, some manufacturers have installed a fuel pressure indicator that senses metered fuel pressure at the fuel distribution valve. Since metered fuel pressure is related to fuel flow, it can provide a means for displaying fuel flow. A pressure indicator that is measuring metered fuel pressure may have the scale marked in terms of fuel pressure, fuel flow, and/or percentage of engine power. With these fuel flow markings, the indicator sometimes is referred to as an analog pressure-type flowmeter. If an analog pressure-type flowmeter is installed as part of the airplane manufacturer's type certificate, a replacement digital or analog fuel flowmeter/fuel totalizer is acceptable, provided the installation meets the applicable airworthiness requirements mentioned in paragraph 5.

(2) Fuel-Injection System with Constant Pressure Pump.

(i) A fuel-injection system with an essentially constant discharge pressure during normal flight engine revolutions normally requires that the fuel be supplied at a positive pressure within specified limits to the fuel-injector inlet. To provide this inlet pressure, the engine-driven fuel pump and the emergency pump are usually installed by the airplane manufacturer. An emergency fuel pump is required by section 23.991(b) and this pump should meet the fuel flow rate of section 23.955; therefore, it will sustain engine operation if the engine-driven fuel pump fails.

(ii) A fuel pressure indicator is required for pump-fed engines in accordance with section 23.1305(g), and is intended for monitoring unmetered fuel pressure at the inlet to the injector. The fuel pressure indicator provides a means for the pilot to determine if the fuel pressure is within safe limits for proper operation.

(iii) Several airplanes have been approved with a fuel pressure indicator connected to the fuel distribution valve where the fuel flow is a function of metered fuel pressure to the discharge nozzle. Metered fuel pressure is related to fuel flow and also relates to engine power output. In some applications, metered fuel pressure has been found acceptable for monitoring fuel pressure and controlling engine performance. The scale on the pressure indicator is to be marked in fuel pressure; in addition, it may be marked in fuel flow and/or percent of engine power output. A fuel pressure indicator at the inlet to the injector provides a more positive means of monitoring the operation of the engine-driven fuel pump and the emergency fuel pump.

(iv) An airplane that has both a separate unmetered fuel pressure indicator and an analog pressure-type flowmeter may have the analog pressure-type fuel flowmeter replaced with a digital fuel flowmeter/fuel totalizer. If only an analog pressure-type fuel flowmeter is installed that actually operates from metered fuel pressure, the analog pressure-type fuel flowmeter may not be replaced with a digital fuel flowmeter/fuel totalizer unless another fuel pressure indicator is installed to sense the fuel pressure at the fuel-injector inlet or an equivalent level of safety for the airplane shows that replacing the fuel pressure indicator with a flowmeter will still meet the applicable airworthiness requirement. A finding of equivalent level of safety should substantiate that the instrumentation provided by the fuel flowmeter is satisfactory, reliable, and safe under all reasonable foreseeable operating conditions.

5. ACCEPTABLE MEANS OF COMPLIANCE. An acceptable method of compliance with the airworthiness standards for installation of fuel flowmeters in small airplanes with continuous-flow, fuel-injection system reciprocating engine is described below.

a. FAA Approval of Technical Data/Installation. Installation of the fuel flowmeter/fuel totalizer may be approved through Type Certification (TC) or Supplemental Type Certification (STC) for the airframe and/or engine. FAA approval is obtained after the applicant shows that the fuel flowmeter/fuel totalizer will perform its intended functions and assures that no unsafe features are incorporated. The need for certification approval for the engine will be determined for each particular installation. Certification approval for the engine is not required when the applicant provides FAA-approved data that shows an alternate configuration that permits a digital flowmeter with specific instructions. An improper installation not only will jeopardize the safety of the present designs, but could also increase probability of system failure. Installations should comply with the airworthiness regulations and with the manufacturer's installation criteria.

b. Airworthiness Considerations.

(1) Fuel-Injection System with Integral Speed Sensing Pressure Pump. Installation of a digital or analog fuel flowmeter may replace the analog pressure-type flowmeter.

(2) Fuel-Injection System with a Constant Pressure Pump. Installation of a digital or analog fuel flowmeter may replace the analog pressure-type flowmeter, provided an unmetered fuel pressure indicator is installed; or it has been determined that replacing the fuel pressure indicator with a fuel flowmeter constitutes an equivalent level of safety.

(3) General Considerations. Changes to the fuel systems should be evaluated for fuel flow rates, maximum allowable pressure drop, hot weather operations, vibration and loads on lines and fittings, fire protection, and powerplant instruments, including effects of glare and reflections on instruments in pilot compartment. An engineering analysis should be made to ensure good engineering practices are incorporated in the design and that the installation is in accordance with airworthiness standards of the following sections: 23.773, 23.955, 23.961, 23.993, 23.1183, 23.1191, 23.1337 and 23.1529 of Part 23. The fire-resistant capability of fuel system components in the engine compartment should be evaluated. The extent and nature of ground and flight evaluations will depend upon each particular installation.

c. Evaluation. Modification of the approved fuel system may have major effects; therefore, an evaluation should be conducted to substantiate continued compliance of the fuel system with airworthiness requirements. FAA approval is issued when all airworthiness requirements are met. The following items should be considered:

(1) Fuel flow transducer should measure the total fuel flow under all operating conditions with either the engine-driven or the emergency fuel pumps. Some fuel systems provide an alternate fuel flow path under different operating conditions; for this reason, the fuel flow transducer must be installed upstream of the alternate fuel flow path.

(2) Fuel flow transducer should be installed downstream of any bypasses or vent returns to the fuel system.

(3) Maximum fuel pressure drop across the fuel flow transducer (normal and blocked conditions) should be within manufacturer's specification and airworthiness requirements. Fuel pressure drop may affect the minimum fuel injector fuel inlet pressure. The minimum fuel injector fuel inlet pressure may require to be redefined, and the instrument range markings on the fuel pressure indicator may need to be revised. Engine-driven pump and emergency or boost pump may require adjustment to higher pressure to account for the added restriction of the transducer. The pumps should be tested to ascertain their capability to

supply the required fuel flow rate at the higher pressure. Flight tests for turbocharged engines may be required to determine that minimum fuel injector inlet pressure meets the engine type certificate data sheet at the maximum approved altitude.

d. Markings and Placards for Powerplant Instruments. Advisory Circular No. 20-88A provides guidelines on markings of airplane powerplant instruments. Sections 23.1541, 23.1543 and 23.1549 of Part 23 provide the airworthiness requirements for instrument markings and placards. The required range markings and/or placards should be furnished with the safe operating limits. A placard should be located near the fuel flowmeter/fuel totalizer display with the following statement: Original equipment fuel quantity indicator is the primary reading of fuel on board the airplane.

e. Airplane Flight Manual (AFM). A flight manual supplement or supplemental AFM and/or placards, if appropriate, should be prepared by the applicant. The information should be presented for FAA approval in the following sections:

(1) Limitation section should include placard information and instrument markings.

(2) Normal procedure section should include information on the operation and function of the equipment. Included in this section should be information that the fuel totalizer does not sense the quantity of fuel in the tanks and it should not be used as a fuel quantity indicator. The accuracy of total fuel remaining displayed on the fuel flowmeter/fuel totalizer is dependent upon the initial fuel supply programmed into the computer before the start of each flight. Uncertainties about initial fuel supply and total fuel remaining can be due to uneven ramp, unusual loading, volume changes of the fuel due to temperature variations, malfunctions such as leaks, siphoning action, collapsed bladder, and other factors; therefore, the total fuel remaining should be verified with the fuel quantity indicator. Before flight, it is essential that the pilot determine that the fuel programmed into the computer is the same as the usable fuel on board the airplane.

(3) The emergency procedure section should include any system malfunction that may occur due to electrical power failure and the procedures for verifying proper operation after power outages.

(4) If the certification basis does not require an AFM with the airplane, the applicant may provide a supplemental AFM, or provide the necessary information to the pilot by means of placards.

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