U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: TYPE CERTIFICATION OF AUTOMOBILE GASOLINE IN PART 23 AIRPLANES WITH RECIPROCATING ENGINES

Date: 3/2/95
Initiated by: ACE-100

AC No: 23.1521-1B
Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance concerning an acceptable means, but not the only means, of compliance with part 23 of the Federal Aviation Regulations (FAR), for approval/certification to use automobile gasoline with or without oxygenates (alcohols, ethers, etc.) in part 23 airplanes. These procedures also apply to those airplanes approved/certificated under previous regulations superseded by part 23. Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation. This AC may be used for certification of automobile gasoline that contains not more than 11 percent by volume of alcohol. Gasoline containing more than 11 percent by volume of alcohol should be certificated using the guidance in AC 23.1521-2.

2. CANCELLATION. AC 23.1521-1A, Certification of Non-Oxygenated Automobile Gasoline (Autogas) Instead of Aviation Gasoline (Avgas) in Part 23 Airplanes with Reciprocating Engines, dated January 2, 1991, is canceled.

3. RELATED FAR SECTIONS.

a. Section 23.1521(d) - Fuel grade or designation

b. Section 23.961 - Fuel system hot weather operation

c. Section 23.955 - Fuel flow

4. RELATED READING MATERIAL. Refer to appendix 1 for related reading material.

5. BACKGROUND.

a. In accordance with prior policy (Engine and Propeller Directorate letter dated November 14, 1986), airplanes and engines listed in the U.S. Department of Commerce Aeronautics Branch document titled, Chapter XIII - Approved Aircraft Engines and Accessories, dated May 1, 1931, may use any type of gasoline in the airplanes. This does not include gasolines containing ethanol, methanol, or other oxygenate additives except methyl-tertiary-butyl-ether (MTBE).

b. In accordance with prior policy (Small Airplane Directorate letter dated October 27, 1989), airplanes that have been previously approved for operation on automobile gasoline, in combination with an automobile gasoline approved alternate engine, can be field-approved provided there are no changes to the airplane or engine and the engine fuel system originally approved for automobile gasoline has a gravity type fuel system. Consideration must be given to larger fuel flow requirements of larger engines. This finding would require an engineering evaluation of the appropriate airplane and engine Supplemental Type Certificates (STC's) and/or corresponding data to ensure no changes were made to the original fuel system. This decision to allow field approval must be made by the appropriate aircraft certification office (ACO). This applies only to the automobile gasoline portion of an engine change. There may be other certification issues that must be addressed.

c. Section 23.1521(d) requires the minimum fuel grade be established so that it is not less than that required for the operation of the engine within the limitations of § 23.1521(b) and (c). The Type Certificate Data Sheet (TCDS) for the engine specifies the minimum grade aviation gasoline that has been established during type certification of the engine. Aviation Grades 80/87, 100/130, and 100LL fuels are common aviation gasolines approved for airplane engines.

d. In recent years, some petroleum manufacturers have discontinued the production of Grade 80/87 aviation fuel. Therefore, several alternate fuels have been proposed for normally aspirated or supercharged, fuel-injected, or carbureted low-compression engines that were approved for operation on Grade 80/87 octane fuel.

e. STC's may be issued to authorize use of unleaded or leaded automobile gasoline in small airplanes approved under part 3 of the CAR or part 23 of the FAR. Two STC's are required for each different airplane--one for the engine and one for the airplane. These STC's are issued when the applicant demonstrates to the FAA that the modification meets the applicable FAR's. An STC issued to authorize automobile gasoline in one airplane does not automatically apply to other airplanes, regardless of whether it is powered by the same engine. All STC data (drawings, reports, etc.) developed by an applicant are proprietary. An airplane owner seeking authorization to use automobile gasoline can develop his own data to pursue STC approval (for engine and airplane) from the FAA. Alternatively, if STC's have already been issued applicable to his model engine or airplane, the airplane owner may purchase these STC's from their owner and modify his engine or airplane in accordance with the associated technical data. The airplane STC should identify the engine STC as prerequisite under the limitations.

f. Specifications for automobile gasoline as well as aviation gasoline have been developed by the American Society for Testing and Materials (ASTM). These specifications are ASTM D 910 for aviation gasolines and ASTM D 439 or ASTM D 4814 (latest revision) for automobile gasoline. Automobile gasoline not containing oxygenates conforming to D 439 and D 4814 are essentially identical and may be used interchangeably. ASTM D 4814 is intended to describe both straight gasoline and gasoline-oxygenate blends. Care must be used in selecting automobile gasoline for aviation use because automotive gasolines may not be manufactured in accordance with these ASTM specifications and also may contain oxygenates that are not included in the STC approval. These gasoline oxygenates may be harmful to aviation fuel systems and engine operation and should be avoided unless approved for use in the airplane. As defined by ASTM specifications D 439 and D 4814, an oxygenate is an oxygen-containing ashless organic compound such as an alcohol or ether that may be used as a fuel or fuel supplement. The data submitted to document the fuel used should include the fuel composition (including oxygenates) and test methods as well as identify the test laboratory or organization performing the fuel tests. This data may be supplied by the fuel manufacturer if the manufacturer has maintained control of the fuel. On December 14, 1992, the FAA approved (without additional testing) the use of MTBE in automobile gasoline for those previously issued automobile gasoline STC's (Small Airplane Directorate letter dated December 14, 1992).

g. ASTM D 910, Standard Specification for Aviation Gasolines, allows the use of isopropyl alcohol conforming to the requirements of ASTM D 4171, Specifications for Fuel System Icing Inhibitor, as a fuel system icing inhibitor. Accordingly, isopropyl alcohol conforming to ASTM D 4171 may be used in concentrations up to 1 percent by volume, to benefit safety, as an icing inhibitor in automobile gasoline. The addition of isopropyl alcohol may reduce antiknock ratings. Therefore, tests performed to obtain approval for the fuel should be accomplished with fuel containing 1 percent by volume of the D 4171 isopropyl alcohol if the addition reduces the antiknock rating and antiknock rating is critical to the test being performed.

6. ACCEPTABLE MEANS OF COMPLIANCE.

a. Engine STC. It is mandatory that the engine be approved (by STC or type certificate (TC)) for operation on automobile gasoline before automobile gasoline is eligible for approval in the airplane. AC 20-24B describes an acceptable method of obtaining approval for the engine to operate on automobile gasoline. Engines that are approved for operation on 80/87 grade aviation fuel, or normally aspirated engines that have a compression ratio of approximately 7.2:1 or less, may operate satisfactorily on automobile gasoline. Engines having a compression ratio greater than 7.2:1 may experience detonation with associated engine destruction when operating on low-octane automobile gasoline. In either case, operation of the engine with any alternate fuel must be shown to meet the minimum design requirements for the engine and be approved. It may be possible for testing of the engine and airplane to be conducted concurrently.

b. A certification test plan and schedule should be prepared by the applicant and presented to the appropriate FAA ACO for acceptance. The test plan should include a description of the test program and equipment that the applicant proposes to use in demonstrating the airworthiness of the fuel to be approved. The engine(s) and airplane fuel system(s) and oil system(s) components should be subjected to a pretest and post-test inspection to verify their conformity and condition prior to and after testing. The test procedures should provide all the specific information required to perform the tests (i.e., test fuel specification, test location, engine model to be tested, specific test hardware and instrumentation to be used, engine minimum and maximum operating parameters, engine lubricant to be used, lubricant change interval, list of all information to be recorded during the test including changes to oil properties, intervals at which this data is to be recorded, etc.).

c. Prior to FAA authorization for test, the applicant should submit a report to substantiate that the fuel under the conditions in which it will be used in the airplane is compatible with the applicable engine and airplane materials. The data should include compatibility with materials, lubricants, and additives that are approved for the engine, propellers (where applicable), and the airplane.

d. At the completion of the airplane tests, a report should be submitted that includes at least the following:

(1) A description of the airplane and engine(s) in which the fuel was tested.

(2) A chronological history of test conditions and engine performance, including r.p.m., power or thrust levels achieved during the test, fuel and oil consumption, oil changes, parts replacement, and other pertinent test results.

(3) An analysis of lubricating oil samples taken before and after the test and before each oil change.

(4) An analysis of material collected in the fuel and oil filters after the test and when filters are changed.

(5) An analysis of the fuel used during the test. For substantiation testing, this analysis should demonstrate minimum or "worst case" properties for the particular test, such as, detonation, fuel system or carburetor icing, altitude restart, and hot weather operation. Distinct fuels may be required to address specific characteristics critical to these substantiation tests.

(6) A description of abnormal wear, deposits, metal attack, or other harmful effects that occurred as a result of the test.

(7) A description of deterioration, excessive seal swelling, shrinkage, hardness, or unsatisfactory condition on or in any of the fuel or oil-wetted parts that occurred as the result of the test.

e. Airplane STC. The evaluation of an application for STC of an airplane for operation on automobile gasoline should consider the following items:

(1) The fuel must be approved by STC or TC for use in the engine.

(2) An analysis of the fuel used for the test should be accomplished. For certification testing, the analysis should demonstrate minimum or critical properties and should include the amount by type of oxygenates in the fuel.

(3) A hot weather operation test in accordance with § 23.961 should be conducted. The airplane should be tested to the maximum altitude for which approval is requested with the critical fuel. The critical fuel is considered one having a volatility Class E or winter grade from a northern geographical class of the United States with an antiknock designation [(R+M)/2] of 87. Refer to ASTM D 439 and/or D 4814 for location and seasonal variations of automobile gasoline. This fuel should be available on the open market for those regions of the United States. The test fuel should be analyzed for compliance with the limits of the ASTM D 439 and/or D 4814. The following tests should be conducted (Test Procedure II and Test Procedure III apply only to airplanes with suction lift fuel systems):

(i) Test Procedure I.

(A) Use fuel with an antiknock designation of 87 and a Reid Vapor Pressure of 12.5 minimum.

(B) Keep fuel cooled from delivery at refinery to installation in the test airplane at a temperature of 11°C (52°F) or cooler in a nonvented container. Drain entire airplane fuel system prior to placing the test fuel in the fuel tanks.

(C) Fuel the aircraft with a minimum safe amount of automotive gasoline and heat to a temperature of 43°C (110°F+0-5°F). (Reference AC 23.961-1).

(D) Prepare the airplane for takeoff in a manner that will ensure the fuel temperature does not fall below the values listed in (C) above.

(E) Refer to AC 23.961-1 for test procedures.

(ii) Test Procedure II.

(A) Service experience indicates that the following test should be conducted on airplanes proposed for certification on automotive gasoline. Use fuel identified in 6e(3)(i)(A) and (B) above, fuel the airplane with a minimum safe amount of fuel, and heat to 29°C (85°F ±2°F). Prepare the airplane for takeoff in a manner that will ensure the fuel temperature does not fall below 28°C (83°F).

(B) Refer to AC 23.961-1 for test procedures.

(iii) Test Procedure III. Service experience indicates that the following test should be conducted on airplanes proposed for certification on automotive gasoline when the main fuel tanks are at or below any pump on a suction lift fuel system. Subsequent to completing 6e(3)(ii)(A) and (B) above, park the airplanes on the ramp with ambient air temperature of 80°F or higher. Allow airplane to sit on the ramp a minimum of 15 or a maximum of 30 minutes to heat soak. Without refueling, start engine, taxi, complete normal preflight, takeoff, climb to 3000 feet AGL, return, and land. Ensure that there are no abnormal engine operating characteristics.

(4) Evaluate the inflight restart envelope with the fuel (§ 23.903(f)). Restart procedures should be placed in the flight manual (paragraph 6e(12).

(5) Engine cooling tests, in accordance with § 23.1041, should be evaluated for compliance with the regulations if the fuel flow rate or fuel net heat of combustion is different.

(6) Evaluate for normal engine operation during all approved aircraft maneuvers; e.g., takeoff and landing, balked landing, etc. Also engine operation when changing from one tank to another, in accordance with § 23.955(e), should be evaluated. The stall test should be conducted first with aviation gasoline to ensure that the test pilot is aware of the normal airplane operation.

(7) Carburetor heat rise test, in accordance with § 23.1093, should be evaluated for compliance with regulations if the fuel freezing point or fuel icing inhibitors are different.

(8) Suction lift fuel systems are more critical than pressure feed systems with respect to vapor formation and should be evaluated for operational problems.

(9) Evaluate the engine for proper operation and confirm that engine rated horsepower is within the limitations specified on the applicable airplane TCDS. Airplanes with fixed pitch propellers can be evaluated by determining the static r.p.m. and manifold pressure are within TCDS limits. If engine power is degraded with use of automobile gasoline, evaluation of these effects on airplane performance is necessary. Detonation testing with critical specification fuel should be accomplished on turbocharged engines.

(10) Establish compatibility of fuel systems material (elastomers, sealants, seals, liners, hoses, etc.) with automobile gasoline. Industry standards such as SAE procedures and ASTM specifications may be used to establish compatibility.

(11) Establish compatibility of fuel quantity gauging system with automobile gasoline. Industry standards such as SAE procedures and ASTM specifications may be used to establish compatibility.

(12) Preparation of a Supplemental Airplane Flight Manual (AFM) or AFM Supplement, as applicable, is necessary to specify the airplane's proper operating procedures and limitations. A Supplemental AFM is used with airplanes that were originally certificated without an AFM, whereas an AFM Supplement is used with airplane models having an AFM. Procedures for determining that the fuel contains only approved materials such as oxygenates, and meets the minimum specification for which approval was obtained, should be provided by the applicant and should be included in the AFM. Test methods contained in ASTM D 4814 may be used or alternate test methods may be presented by the applicant to the FAA for acceptance. It is the operator's responsibility to determine that the fuel used satisfies the approved fuel requirements. AC 20-43C contains advisory material concerning fuel handling procedures and methods to prevent contamination. Procedures for mixing automobile gasoline and aviation gasoline should be addressed.

(13) Specify appropriate markings and placards (§ 23.1541) to define the approved fuels and any operating limitations. The appropriate fuel specification such as ASTM D 439 and/or D 4814 and approved oxygenates should be included. Specify a placard to alert the pilot of a Supplemental AFM or AFM Supplement for proper operation.

(14) The Flight Manual Supplement or Supplementary Flight Manual should contain the following caution: "Care should be used when selecting automobile gasoline for aviation use because the automotive gasolines may not be produced in accordance with ASTM

specifications D 439 or D 4814. Gasolines conforming to the ASTM specifications D 439 or D 4814 and that contain only approved oxygenates or other additives should be used. Gasolines containing unapproved oxygenates may be harmful to aviation fuel systems and engine operation and should be avoided."

(15) The Flight Manual Supplement or Supplementary Flight Manual should contain a caution stating the following: "All airport, local, state, and federal regulations pertaining to airplane fueling operation must be complied with."

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APPENDIX 1. RELATED READING MATERIAL

1. ADVISORY CIRCULARS (AC's). The AC's listed below can be obtained from the U.S. Department of Transportation, General Services Section, M-443.2, Washington, D.C. 20590. AC 23-8A is for purchase and can be obtained from the Superintendent of Documents, PO Box 371954, Pittsburgh, PA 15250-7954, or from any of the Government Printing Office Bookstores located in major cities throughout the United States.

a. AC 20-24B, Qualification of Fuels, Lubricants, and Additives for Aircraft Engines, dated December 20, 1985.

b. AC 20-43C, Aircraft Fuel Control, dated October 20, 1976.

c. AC 23-8A, Flight Test Guide for Certification of Part 23 Airplanes, dated February 9, 1989, (SN 050-007-00817-1). AC 23-8A Change 1, dated August 30, 1993, (SN 050-007-01013-3).

d. AC 23.955-1, Substantiating Flow Rates and Pressures in Fuel Systems of Small Airplanes, dated June 10, 1985.

e. AC 23.959-1, Unusable Fuel Test Procedures for Small Airplanes, dated January 14, 1985.

f. AC 23.961-1, Procedures for Conducting Fuel System Hot Weather Operation Tests, dated January 14, 1987.

g. AC 23.1521-2, Type Certification of Oxygenates and Oxygenated Gasoline Fuels in Part 23 Airplanes with Reciprocating Engines, dated January 21, 1993.

h. AC 33.47-1, Detonation Testing in Reciprocating Aircraft Engines, dated June 27, 1988.

i. AC 91-33A, Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline, dated July 18, 1984.

2. AMERICAN SOCIETY FOR TESTING AND MATERIALS (ASTM) STANDARDS. The ASTM Standards listed below can be obtained from ASTM, 1916 Race Street, Philadelphia, PA 19103:

a. ASTM D 910, Standard Specification for Aviation Gasolines, dated October 31, 1988, or later revision.

b. ASTM D 439, Standard Specification for Automotive Gasoline, dated October 31, 1988, or later revision.

c. ASTM D 4814, Standard Specification for Automotive Spark-Ignition Engine Fuel, dated October 31, 1988, or later revision.

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