U.S. Department of Transportation
Federal Aviation Administration

Advisory Circular

Subject: MINIMUM FLIGHTCREW

Date: 2/2/93
Initiated by: ANM-110

AC No: 25.1523-1
Change:

1. PURPOSE. This advisory circular (AC) sets forth a method of compliance with the requirements of § 25.1523 of the Federal Aviation Regulations (FAR), which contains the certification requirements for minimum flightcrew on transport category airplanes. As with all AC material, it is not mandatory and does not constitute a regulation. It is for guidance purposes only.

2. RELATED FAR SECTIONS. Section 25.1523 of the FAR, as amended through Amendment 25-3.

3. BACKGROUND. In early 1981, the President established a task force on aircraft crew complement which was directed to make "its recommendation whether operation of the new generation of commercial jet transport airplanes by two-person crews is safe and certification of such airplanes is consistent with the Secretary's duty under the certification provisions of the Federal Aviation Act of 1958 to promote flight safety." Several recommendations were made in the Report of the President's Task Force on Aircraft Crew Complement, dated July 2, 1981, including one that suggested that the agency complete and keep current Section 187 (Minimum Flightcrew) of FAA Order 8110.8, Engineering Flight Test Guide for Transport Category Airplanes. The agency agreed with the recommendation and took steps to complete these criteria for inclusion into the Order. However, in late 1982 the agency decided to upgrade the entire contents of the Order to advisory circulars to make such material formally available to the general public.

4. DISCUSSION.

a. Under § 25.1523, the minimum flightcrew for a transport category airplane must be established so that it is sufficient for safe operation considering:

(1) The workload on individual crewmembers;

(2) The accessibility and ease of operation of necessary controls by the appropriate crewmembers; and

(3) The kind of operation described in § 25.1525.

b. The criteria used in making the determinations required by § 25.1523 are set forth in Appendix D of Part 25.

c. The procedures for determining compliance with § 25.1523 and Appendix D may vary in complexity depending on whether the certification is:

(1) A new model;

(2) A follow-on model;

(3) A modification to reduce the original crew size of an already approved airplane; or

(4) A type design change or supplemental type certificate (STC) program expected to result in a substantial increase in the workload of any flight crewmember.

d. Although § 25.1523 addresses the accessibility and ease of operation of necessary controls in addition to individual workload, the methods of evaluating workload are far less straightforward, and usually dominate the determination of the minimum flightcrew. Further, Part 25 contains no rules specifically addressing the human factors issues encountered in workload evaluations, so that consideration of such issues tend to be viewed as falling into minimum crew evaluations. It is recognized that the size of the minimum flightcrew is usually fixed by the applicant's design from the outset. The purpose of the evaluations conducted under § 25.1523 is to corroborate by demonstration the predicted crew workload submitted by the applicant to substantiate compliance with § 25.1523, and to provide an independent and comprehensive assessment of individual crewmember workload in a realistic operating environment. Any problems encountered would probably be resolved by system redesign or procedural changes to redistribute workload more evenly.

e. Discussions on crew complement and the associated crew workload between the involved FAA Aircraft Certification Office and the manufacturer should take place early in the development cycle. These discussions should focus on identification of design features that are likely to impact crew workload. Subsequent analyses, demonstrations, and tests should be structured to verify that these design features do not place excessive workload demands on any crewmember. Crew duties and tasks for each crewmember should be appropriate to assure continuous involvement and awareness.

5. CERTIFICATION PROCEDURES.

a. General.

(1) A systematic evaluation and test plan is required for any new or modified airplane. Methods for substantiating compliance with § 25.1523 should include use of acceptable analyses, simulator demonstrations, and/or flight tests. Flight tests can confirm the analytical or simulator predictions. The minimum crew complement's workload should be studied through a logical process of analysis, measurement, and demonstration of the workload imposed by a particular flight deck design.

(2) Appropriate analysis should be conducted by the applicant early in the design process. The specific method(s) of analysis should be selected on the basis of its predictive validity, reliability, applicability to the particular flight deck configuration with emphasis on modification or new equipment, and availability of a suitable reference for comparison.

b. Analytical Approach.

(1) One acceptable analytical approach assesses workload as a percentage of the time available to perform tasks (Time Line Analysis). This process should be applied to an appropriate set of flight segments in which operationally important time constraints can be identified. This method is satisfactory for evaluation of flight deck changes relating to overt pilot tasks such as control movements and data inputs. The generally accepted practice involves careful selection of a limited set of flight scenarios and time segments that represent the range of operational requirements (including the range of selected normal, non-normal, and emergency procedures). Task-time line analysis yields useful data when tasks must be performed within operationally significant time constraints. An accurate determination of the time available is critical if this method is to have any value. Measurements of time that result from such analysis cannot be interpreted by any absolute standards, but such records can be used to identify increased workload demands for use in subsequent testing in a simulator or airplane, and comparison can be made with appropriate workload demands for in-service airplanes. The impact of flight deck changes on the tasks involved with planning and execution of emergency or non-normal procedures should receive particular evaluation.

(2) The most frequently used basis for deciding that a new design is acceptable is a comparison of a new design with a previous design proven in operational service. By making specific evaluations using scenarios designed to exercise the new design features and comparing the results to a known baseline, it is possible to proceed with confidence that the changes incorporated in the new designs will accomplish the intended result. If the new design represents an evolutionary improvement of the reference flight deck without additions of major systems affecting crew workload, direct comparisons are possible. Service experience of the reference flight deck and airplanes having systems similar to the new design should be reviewed to assure that any existing problems are understood and not perpetuated or inappropriately increased by the new design.

(3) If preliminary analyses by the certification team identify potential problem areas, these areas should receive more extensive evaluation and data collection. These concerns should be adequately addressed in the manufacturers' test or certification plan when submitted to the FAA.

(4) If the new design represents a significant change in the level of automation or pilot duties, analytic comparison to a reference design may have a lesser value. Without firm data on the time required to accomplish both normal and contingency duties, realistic simulation and/or flight tests may be required for validation.

c. Testing.

(1) The final decision on minimum crew determination is to be reserved until the airplane has been flown by experienced and properly qualified pilots trained and current in the operation of the airplane. The pilots who perform these evaluations should not be limited to manufacturers' test pilots and FAA certification pilots. It is highly recommended that some evaluation be conducted by "line pilots" who routinely fly similar airplanes and who can base their judgment on operational experience. Appendix D of Part 25 contains the criteria for determining the minimum flightcrew under § 25.1523 (basic workload functions and workload factors).

(2) The test program should address all workload functions and factors listed in § 25.1523 and Appendix D. For example, an evaluation of workload should include the communications tasks required to properly operate the airplane in the environment for which approval is sought. The goal is to evaluate workload with the proposed crew complement during realistic operating conditions, including representative air traffic, weather, airline operational duties, and appropriate company and cabin communications.

(3) Evaluation pilots should assure that new systems and rearranged cockpit configurations will be evaluated using scenarios representative of the type of operation for which the airplane is intended. Although quantitative substantiating crew workload data will often be provided, the current state-of-the-art relies on structured subjective evaluations. These evaluations compare the ease of execution of crew tasks in the subject airplane with that experienced in the reference cockpits in identical or substantively similar scenarios.

(4) A proposed flight test program for showing compliance with § 25.1523 and Appendix D of Part 25 should be submitted by the applicant and should be structured to address the following factors:

(i) Route. The test program routes should be constructed to provide a representative mix of navigation aids, airports, instrument approaches and Air Traffic Control (ATC) services.

(ii) Weather. The routes should be selected to provide the likelihood of encountering types of adverse weather appropriate to the airplane's intended operation (IMC conditions, night, turbulence, icing, etc.).

(iii) Crew Work Schedule. The test crew should be assigned to a daily work schedule that is representative of the type of operations for which the airplane was developed. The program should include the duration of the work day and the maximum expected number of departures and arrivals, flights which begin at night, maximum allowable duty times, and minimum rest periods.

(iv) Minimum Equipment List. The applicant should incorporate representative dispatch configurations in the proposed flight test program. Combinations of these representative dispatch configurations with probable subsequent simulated malfunctions should form the basis of many of the evaluation scenarios.

(v) Traffic Density. The airplane should be operated on routes that would adequately sample high density areas in both IMC and VMC, but should also include precision and nonprecision approaches, holdings, missed approaches, and diversions to alternate airports.

(vi) Incapacitated Crewmember.

(A) The NTSB accident data indicates that there were 262 occurrences of pilot incapacitation in Part 91 operations from January 1980 through July 1989, that resulted in 180 fatalities. All these fatalities were attributed to single pilot operation. Similar NTSB data from the same time period reveals 32 occurrences of pilot incapacitation in Part 135 operations resulting in 32 fatalities. All fatalities were attributed to single pilot operation. Relative to Part 121 operations over the same time period, there were 51 pilot incapacitation occurrences which resulted in a normal recovery of the aircraft by the other pilot.

(B) Whenever the applicable operating rule requires a minimum flightcrew of at least two pilots, the certification program should include a demonstration of operations during the total incapacitation of a crewmember at any point in a given flight. It must be shown that the airplane can be operated safely and landed safely with the remaining crew at a planned or unplanned destination. Incapacitated crewmember tests need not be additive to all other "dispatch plus subsequent failure" scenarios. Incapacitation should be viewed as another example of "subsequent failure" to be included within one or more scenarios beginning with a dispatch configuration which includes selected items from the proposed Minimum Equipment List. Although Part 25 does not specifically disallow certification of single piloted transport category airplanes, the FAA has been reluctant to approve this operation when all aspects of the intended use of the airplane and the consequences of pilot incapacitation are considered, as well as the historical accident record noted in Paragraph (A) above.

(vii) System Failures. The consequences of changes from normal to failed modes of operation should be included in the program. Both primary and secondary systems should be considered and representative combinations of failures should be included. (See note in Paragraph 5c(4)(viii).)

(viii) Emergency and Non-normal Situations. A sampling of various emergencies and non-normal conditions should be established in the test program to show their effect on the crew workload. Note: Prior to selecting the system failures that will be evaluated in the flight test program, it is necessary to conduct simulation or analytical studies. The crew workload distribution during the execution of emergency or non-normal situations should be understood to assure selection of appropriate failure cases.

(5) Guidelines concerning the implementation of a selected number of subjective, physiological, and performance workload measurement techniques, is contained in the FAA report "Assessment of Crew Workload Measurement Methods, Techniques, and Procedures" Vol. II (Report No. WRDC-TR-89-7006).

d. Recording Flight Test Data.

(1) The members of the type certification team who serve as pilots and observers should be supplied with subjective workload assessment questionnaires tailored to match the extent of the evaluation. If the flight deck is altered from a previously approved and fully satisfactory configuration by the addition of a single new system, for example, the evaluation can be limited and specific as to scenarios and questionnaires. For a complete new flight deck and a reduction in previously approved minimum crew, a complete workload assessment covering all phases of flight should be conducted, with correspondingly complete evaluation questionnaires. In addition there should be in-flight observer forms that provide means to record crew performance, crew errors, missed communications, and problems with checklists, flight management or flight guidance systems, or a structured debrief questionnaire and interview after the flight designed to identify operational situations experienced in flight. For the purposes of this data gathering, the airplane should be configured to allow the team evaluators to observe all crew activities from the cockpit and to hear both external and internal communications.

(2) The regulatory criteria as well as individual flightcrew ability, differences with the reference airplane, and variations in the test environment, are not conducive to analyses that use precise measurements. Instead, coarse rankings of the perceived workload factors listed in Part 25, Appendix D, should be sought, and compared to either a baseline model or the evaluator's impressions of a typical workload in similar current design airplanes. Areas of increased workload due to external elements, system failures, individual differences in ratings, and quantity and impact of crew errors must be understood and resolved. Increase workload does not necessarily make the airplane under evaluation unacceptable. However, to be acceptable, it must be a consensus of the certification team members that all of the workload elements specified in Part 25, Appendix D, can be accomplished by appropriately rated and trained pilots.

e. Additional Workload Test Methods.

(1) If a new airplane design incorporates changes not assessable by traditional test methods, alternative methods should be proposed by the manufacturer with sufficient substantiating data to assess the validity, reliability and applicability of the method.

(2) Comparisons may be required between the speed and accuracy of problem resolution or workload in a conventional versus a modified flight deck design or with conventional versus modified handling qualities. In any case, it should not be presumed that traditional test methods are appropriate for all new designs.

f. Involvement of Third Parties. Responsibility for the preparation of the data collection and analysis plan rests with the applicant. The FAA is responsible for assuring that the plan incorporates valid and reliable measures of crew workload that are viewed by experts as representative of current knowledge and developments. The FAA will, and applicants are encouraged to, consult with other government and industry specialists to achieve this objective.

6. CHECKLIST OF EVENTS. Summarized in chart form (see APPENDIX 1) are the sequential stages of implementation of § 25.1523. For each briefly described action, it is indicated when the procedures should be initiated and completed, and who has the primary responsibility for planning and executing the step.

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APPENDIX 1. SECTION 25.1523 CERTIFICATION SEQUENCE

	EVENT	TIME	RESPONSIBILITY
1.	Familiarize FAA with flight deck design features.	Program inception to specification of prototype.	Manufacturer *
2.	Decision as to general nature of the minimum flightcrew program. New models? Follow-on? Modification?	Prior to specification of prototype.	FAA (Manufacturer)
3.	Preparation of overall certification plan for demonstration of compliance with § 25.1523.	After decision of the general nature of minimum flightcrew program.	Manufacturer
4.	Final flight deck design/prototype specifications.	Upon completion of necessary design studies/market analyses.	Manufacturer
5.	Review of applicant's plan. Identification of issues.	Preliminary TCB meeting.	FAA Manufacturer
6.	Preliminary decision on resolution of crew workload issues. Identification of remaining issues.	Upon receipt by FAA.	FAA
7.	Conduct planned studies/simulations/ analyses.	Prior to certification.	Manufacturer (FAA)
8.	Preparation of preliminary MEL - flight manual.	Prior to flight test for § 25.1523.	Manufacturer (FAA)

9.	Preparation of detailed test plan for demonstration of compliance with § 25.1523.	Prior to flight test for § 25.1523.	Manufacturer (FAA)
10.	Decisions on flight test plan requirements for flight test.	Upon completion of ground studies.	FAA
11.	Conduct flight tests.	From flight test plan.	Manufacturer/FAA

* Customer participation in all phases of flight deck evaluation is implicit in the manufacturer's responsibilities. Consultation between the manufacturer and customers is continuous from inception through the phase of airplane delivery, and until completion of airplane service life.

( ) Indicates secondary responsibility

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Advisory Circular

Subject: CERTIFICATION OF NON-OXYGENATED AUTOMOBILE GASOLINE (AUTOGAS) INSTEAD OF AVIATION GASOLINE (AVGAS) IN PART 23 AIRPLANES WITH RECIPROCATING ENGINES

Date: 1/2/91 Initiated by: ACE-100

AC No: 23.1521-1A Change:

1. PURPOSE. This advisory circular (AC) provides information and guidance concerning an acceptable means, but not the only means, of compliance with part 3 of the Civil Air Regulations (CAR) and part 23 of the Federal Aviation Regulations (FAR), applicable to approval procedures covering use of autogas in part 23 airplanes. These procedures also apply to those airplanes approved under part 4a of the CAR. Accordingly, this material is neither mandatory nor regulatory in nature and does not constitute a regulation.

2. CANCELLATION. AC 23.1521-1, Approval of Automobile Gasoline (Autogas) in lieu of Aviation Gasoline (Avgas) in Small Airplanes with Reciprocating Engines, dated January 25, 1985, is cancelled.

3. RELATED FAR SECTIONS. For convenience, the related sections of CAR, part 3 reference, corresponding to the sections of FAR, part 23, are shown in parenthesis.

a. Section 23.1521(d) (3.744(c)).

b. Section 23.961 (3.438).

c. Section 23.955 (3.429).

4. RELATED READING MATERIAL. The advisory circulars listed below can be obtained from the U. S. Department of Transportation, Utilization and Storage Section, M-443.2, Washington, D.C. 20590. AC 23-8A can be obtained from the Superintendent of Documents, U. S. Government Printing Office, Washington, D.C. 20402, or from any of the Government Printing Office bookstores located in major cities throughout the United States. The American Society for Testing and Materials (ASTM) Standards listed below can be obtained from ASTM, 1916 Race Street, Philadelphia, PA 19103.

a. "Qualification of Fuel, Lubricants, and Additives for Aircraft Engines," AC 20-24B, Federal Aviation Administration, December 20, 1985.

b. "Aircraft Fuel Control," AC 20-43C, Federal Aviation Administration, October 26, 1976.

c. "Flight Test Guide for Certification of Part 23 Airplanes," AC 23-8A, Federal Aviation Administration, February 9, 1989.

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

e. "Unusable Fuel Test Procedures for Small Airplanes," AC 23.959-1, Federal Aviation Administration, January 15, 1985.

f. "Procedures for Conducting Fuel System Hot Weather Operation Tests," AC 23.961-1, Federal Aviation Administration, January 14, 1987.

g. "Detonation Testing in Reciprocating Aircraft Engines," AC 33.47-1, Federal Aviation Administration, June 27, 1988.

h. "Standard Specification for Aviation Gasolines," ASTM D 910, American Society for Testing and Materials, October 31, 1988.

i. "Standard Specification for Automotive Gasoline," ASTM D 439, American Society for Testing and Materials, October 31, 1988.

j. "Standard Specification for Automotive Spark-Ignition Engine Fuel," ASTM D 4814, American Society for Testing and Materials, October 31, 1988.

k. "Use of Alternate Grades of Aviation Gasoline for Grade 80/87 and Use of Automotive Gasoline," AC 91-33A, Federal Aviation Administration, July 18, 1984.

5. BACKGROUND.

a. In accordance with prior policy, airplane 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, methyl-tertiary-butyl-ether (MTBE), or other oxygenate additives.

b. In accordance with prior policy, airplanes that have been previously approved for operation on autogas, in combination with an autogas 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 autogas 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. This applies only to the autogas portion of an engine change. There may be other certification issues that must be addressed.

c. Section 23.1521(d) (3.744(c)) 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 grade 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 autogas 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 autogas 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 autogas 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 autogas as well as avgas 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 for autogas. Autogases not containing alcohol or other oxygenates, conforming to D 439 and D 4814 are essentially identical and may be used interchangeably. Care must be used in selecting autogas for aviation use because many automotive gasolines are not manufactured in accordance with these ASTM specifications and may contain alcohol and other oxygenates. These gasoline additives may be harmful to aviation fuel systems and engine operation and should be avoided. Gasolines conforming to these ASTM specifications and that do not contain alcohol or other oxygenates are the only current FAA approved autogas fuels for aviation use. 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. Accordingly, MTBE is an

oxygenate and approvals for use of autogas do not include MTBE or blends/mixtures of MTBE. The data submitted to document the fuel used should include the fuel composition and test methods as well as identify the test laboratory or organization performing the test.

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% by volume, to benefit safety, as an icing inhibitor in autogas when approved as part of the STC or amended Type Certificate (TC). Addition of isopropyl alcohol may reduce antiknock ratings. Therefore, the tests performed to obtain approval for the fuel should be accomplished with fuel containing 1% 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 TC) for operation on autogas before autogas is eligible for approval in the airplane. Advisory Circular 20-24B describes an acceptable method of obtaining approval for the engine to operate on autogas. 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 autogas. Engines having a compression ratio greater than 7.2:1 may experience detonation with associated engine destruction when operating on low-octane autogas. 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. Advisory Circular 91-33A contains information on use of alternate grade of avgas in airplanes.

b. A certification test plan and schedule should be prepared by the applicant and presented to the appropriate FAA Aircraft Certification Office (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 must demonstrate minimum or "worst case" properties.

(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. Evaluation of an application for STC of an airplane for operation on autogas 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. The use of autogas containing ethanol, methanol, MTBE, or other oxygenate additives is not acceptable and should be avoided.

(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 of [(R+M)/2] of 87. Refer to ASTM D 439 and/or D 4814 for location and seasonal variations of autogas. 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:

(i) Test Procedure I.

(A) Use winter grade fuel with 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 FAA 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)).

(5) Engine cooling may not be critical; however, engine cooling tests, in accordance with § 23.1041, must be evaluated for compliance with the regulations.

(6) Evaluate for normal engine operation during all approved aircraft maneuvers; e.g., takeoff and landing, balked landing, stall, 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 avgas to ensure that the test pilot is aware of the normal airplane operation.

(7) Carburetor heat rise may not be critical; however, carburetor heat rise test, in accordance with § 23.1093, must be evaluated for compliance with regulations.

(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 autogas, evaluation of these effects on airplane performance is necessary. Detonation testing with critical specification fuel should be accomplished.

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

(11) Establish compatibility of fuel quantity gauging system with autogas. 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 fuel is free of contamination, does not contain unapproved materials such as ethanol, methanol, MTBE, or other oxygenates, and meets the minimum specification for which approval was obtained, should be provided by the applicant and should be included in the AFM. It is the operator's responsibility to determine that the fuel used satisfies the approved fuel requirements. Advisory Circular 20-43C contains advisory material concerning fuel handling procedures and methods to prevent contamination. Procedures for mixing autogas and avgas should be addressed.

(13) Specify appropriate markings and placards (§ 23.1541) to define the approved grade of fuels and any operating limitations. The appropriate fuel specification such as ASTM D 439 and/or D 4814 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 must be used when selecting autogas for aviation use because many automotive gasolines are not manufactured in accordance with ASTM specifications D 439 and D 4814. Gasolines conforming to the ASTM specifications D 439 and D 4814 and that do not contain ethanol, methanol, MTBE, or other oxygenates are the only current FAA approved autogas fuels for aviation use. Gasolines containing these 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."

(16) The above cautions should be added to all previously approved STC's for autogas use.

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