Federal Aviation
Administration

Subject: **ACTION**: Cessna Model 172R Equivalent Level of Safety; Engine Induction Icing; Engine Control and Engine Mixture Control; ACE-96-3

Date: November 7, 1997

From: Carlos Blacklock, Program Manager, ACE-117W, Wichita Aircraft Certification Office

Reply to Attn. of:

To: Manager, Project Support Section, ACE-112, Small Airplane Directorate

BACKGROUND

In order to maintain the same level of operational safety on the redesigned engine system of the Model 172R as compared to the earlier Model 172 series airplanes, the FAA required Cessna to comply with later Part 23 amendments as follows:

(1) Engine induction icing protection, § 23.1093(a)(5), as amended by Amendment 23-43, and;
(2) Engine controls, § 23.1143(g), as amended by Amendment 23-43, and;
(3) Engine mixture controls, § 23.1147(b), as amended by Amendment 23-43.

DISCUSSION OF APPLICABLE REGULATIONS

(1) Compliance with § 23.1093. Cessna has requested to apply only § 23.1093(a)(5) which would arbitrarily require the addition of a preheater in the induction system. § 23.1093(a) allows the option to show "by other means" that the induction system will prevent or eliminate icing. Cessna maintained that the induction system of the Model 172R will not form ice. Cessna has chosen a type of fuel injection system that has shown adverse service experience on other airplane installations. It was determined appropriate, therefore, to apply all of the requirements of § 23.1093, as amended by Amendment 23-43. Analysis alone, was not deemed sufficient to document compliance. As such, Cessna must show by tests, both on the ground and in flight, that the induction system meets these criteria.

(2) and (3) These requirements specify that the throttle and mixture attachments must be designed so that if the control(s) separate at the engine, the airplane is capable of continued safe flight and landing. Literal compliance with these requirements would normally involve the addition of spring devices on the engine.

CESSNA POSITION

(1) Refer to Cessna letter L417-02-95-01, dated November 30, 1995. This letter provided a position regarding the inclusion of FAR § 23.1093(a)(5) in the certification basis.

In (issue paper G-1), the FAA has stated that in order for the Model 172R to "maintain the same level of operational safety on the redesigned [engine installation]...as compared to the earlier Model 172 series airplanes, "Cessna would need to comply with FAR 23.1093 as amended by Amendment 23-43, for engine induction icing protection. Paragraph 23.1093 has always included the requirement that the aircraft be protected from induction system icing as described, "[u]nless...done by other means..." It is Cessna's intention with this letter to show that the Model 172R will meet the safety level of the earlier Skyhawks without using the latest 23.1093(a)(5) means of compliance which requires preheat for icing protection.

The Model 172R is not subject to "carburetor icing" as such, since the air/fuel mixture of the fuel injection system on its Lycoming IO-360-L2A engine installation is not subject to the venturi icing phenomenon common to carburated systems. Instead, the fuel injector/throttle body unit adjusts the amount of fuel supplied to the engine using four impact tubes positioned in the induction airstream. These tubes all provide air pressure to one side of an internal diaphragm, which adjusts fuel flow to the engine based on ram air from the impact tubes compared to static air within the throat of the unit, which is provided to the other side of the diaphragm. If water droplets impinge and freeze on the impact tubes to the extent that all four tubes ice over, the diaphragm fuel metering could conceivably shut off fuel to the engine. In order for this scenario to take place, three conditions would need to exist: 1) visible liquid precipitation would be required, enough to travel through the air filter and be somehow reconverted into water droplets on the other side, 2) the water droplets within the induction system airstream would need to come into contact with all four impact tubes, and 3) ambient air temperatures near freezing would be required, with the impact tubes themselves at or below freezing.

Cessna has had experience with the Model 177/177RG Cardinal aircraft which is nearly identical to the changes proposed for the 172R. When Cessna began to offer the 177RG, the entire induction system changed from a carburated Lycoming O-360() engine to and IO-360() with "Bendix fuel injection. In order to determine the effect this change had upon safety, Cessna's accident investigation group obtained every FAA accident/incident report for the 177-series aircraft which involved any kind of suspected icing, then looked at each report individually to determine which ones involved any kind of suspected icing, then looked at each report individually to determine which ones involved suspected induction system icing. Of the 17 cases of suspected induction system icing, one involved the 177RG--the rest involved carburated Cardinals. This would suggest that a disproportionate number of carburated 177 operators have had unpleasant experiences with the carb heat-equipped aircraft, even accounting for the fact that there are approximately twice as many carburated Cardinals in the field as there are 177RGs.

CESSNA POSITION, CONTINUED

The report for the one Cardinal RG which experienced suspected induction system icing shows that the aircraft performed an emergency landing during an instruction flight on 17 September 1979 near Antioch, California, with no fatalities or injuries. It states that the operator experienced an engine failure during a demonstrated stall, and that "carb ice" was suspected. However, National Weather Service records for the area that day show clear skies, 102°F--impossible conditions for impact tube icing, which require temperatures around freezing and visible liquid precipitation, as stated above. In fact, the entire month of September 1979 for that area shows only clear skies except for one day, which was partly cloudy. Therefore, Cessna believes that, in the U.S. at least, no accidents involving 177RGs have occurred which can be attributed to induction system icing.

In order for the above-stated facts to be useful when considering the Model 172R, Cessna would need to show that the induction system proposed will protect from impingement of water droplets large enough to cause icing of all four impact tubes. To this end, Cessna's Aerodynamics group has mathematically modeled ingested water droplet paths into the fuel injector/throttle body unit (assuming no credit for the air filter), using the VSAERO ICE module. The attached figure shows the induction air path to the throttle body unit, starting just aft of the air filter. As can be seen, the induction air duct travels aft and downward, then makes a sharp turn directly up into the unit. All but the smallest water droplets have been calculated as unable to make this turn up into the engine, and will impact the side of the duct and be harmlessly drained overboard via the drain at the bottom. Therefore, the most important water droplet consideration surrounds the path of the smallest water particles. Using the smallest water droplet size (15 microns) from FAR 25 Appendix C, Cessna's Aerodynamics group has calculated that at least one impact tube will remain open at all times, even without installation of the air filter, which will be considered further. Cessna has performed in-house tests which show that the aircraft will operated with three tubes blocked off, with little or no degradation to aircraft performance.

Cessna believes that water droplet impingement on the impact tubes significant enough to clog all four tubes at once is thus precluded. However, other factors will also help assure safety of the aircraft. For instance, since supercooled water droplets will not be able to pass through the air filter unhindered, they will freeze to and clog the filter before they can get into the induction airstream on the other side. The possibility of such droplets impinging on the impact tubes is thus further avoided.

Near-freezing and above freezing water droplets may work their way through the filter, but will combine with other water trapped in the filter. This buildup of water in the filter will most likely have the effect of increasing water droplet sizes in the induction system airstream as the collected water "splatters", once the filter has become saturated with water. Calculations for larger droplets have shown them to pose no hazard to the aircraft, as shown above. Experience with the 177RG would either tend to support this assumption, or may

CESSNA POSITION, CONTINUED

show that water droplets do not re-enter the induction system airstream inside of the filter. In addition, operation of the auxiliary air inlet to the 172R induction airstream is such that, as soon as the filter starts to restrict airflow, whether due to a wet filter or a clogging filter, a spring-loaded door will open into a plenum on the aft side of the air filter, allowing warmer air from the engine compartment directly into the induction system airstream, increasing alternate airflow as necessary until all induction air is provided by the auxiliary source when the filter becomes completely clogged. As the temperature of the outside water droplets (or the air filter itself)lowers to freezing, warmer air from the auxiliary source will keep the induction air warmer than outside air. Once the water droplets(or the filter)reach freezing temperatures, the air filter will completely clog, water will cease to travel through the filter, and warmer induction air will be pulled from around the engine under the cowling, free of any moisture. Therefore, any possibility of induction system icing conditions will be further precluded.

An additional safety consideration involves the use of carburetor heat in icing conditions. Since the conditions required for impact tube icing are similar to those required for structural icing, the 172R is at an advantage. On carburated airplanes, one of the most likely procedures necessary in structural icing conditions is the need for use of carb heat and/or auxiliary induction air. In such a case, not only would the pilot need to closely monitor engine operation, but when it was deemed necessary to add carb heat, the aircraft would immediately lose some power, which could otherwise be used to carry ice and/or climb more quickly out of icing conditions, because of the power loss associated with use of carb heat. With the fuel-injected 172, Cessna's intention is to design the induction system such that the pilot can concentrate on flying out of icing conditions, as the induction system will protect itself(water droplet ingestion and auxiliary induction air have been addressed). In addition, the 172R will lose less power, even with the air filter entirely clogged, since the aux air provided is not heated to as high a temperature as would be carburetor heat.

The above-listed considerations assume the aircraft to be flying in near-freezing visible moisture at all times. However, it should be noted that the conditions which would be required for induction system icing on the Model 172R are small when compared to the conditions which are conducive to carburetor icing, even without consideration given to the 172R's protection from impact tube ice. On the 172R, conditions would need to be exact, with impact tubes at or below freezing temperatures with extremely small water droplets somehow forming in the induction system airstream. These droplets would need to be generated aft of the air filter for conceivable impact tube icing situations. On carburated aircraft, carb ice is possible over a wide range of temperatures, even with the lack of visible precipitation.

One last point should be considered when assessing safety of the fuel injected 172R. A review of all Model 172 FAA accident and incident reports between January 1973 and the

CESSNA POSITION, CONTINUED

present shows a total of over 170 cases where improper use of carb heat was considered to be a significant contributing factor in the accident or incident. These would include the pilot's failure to use carb heat(or failure to use it in a timely manner)when it was appropriate, partial use of carb heat when full use was call for, and use of carb heat when its use was detrimental to critical aircraft performance. In the vast majority cases, pilot error was considered to be the general cause of the accident or incident. By designing the 172R induction system such that impact tube icing is precluded, and by removing the carb heat control from the cockpit, Cessna believes that one source of pilot error can be removed, thus improving the overall safety of the Skyhawk(although none of the 170+ accidents or incidents referred to resulted in any fatalities).

For the reasons listed above, Cessna believes that the fuel injected Model 172R exceeds the FAA's stated desire to "maintain the same level of operational safety" on the redesigned engine installation. However, it is Cessna's intention to increase safety by the change to the new engine installation, not merely to maintain it. Cessna therefore believes that the intent of FAA Position B(1) for Project No. AT0986WI-A Issue Paper G-1 is met in the 172R.

FAA concurrence and/or input to this letter was requested.

(2) & (3) Refer to Cessna letter L417-02-95-02, dated November 30, 1995. This letter provided a position regarding the inclusion of FAR §§ 23.1143(g) and 23.1147(b) in the certification basis.

In the referenced Issue Paper, the FAA has stated that in order for the Model 172R to "maintain the same level of operational safety on the redesigned [engine installation]...as compared to the earlier Model 172 series airplanes," Cessna would need to comply with FAR 23.1143(g) and 23.1147(b) as amended by Amendment 23-43, for engine controls and engine mixture controls. It is Cessna's intention with this letter to show that the level of safety associated with the fuel injected 172R is in no way degraded when compared to the previous versions of the 172 which have no such requirements for power and mixture controls, and that it will therefore meet the FAA's intention to maintain operational safety.

Each year, the FAA receives reports of throttle or fuel mixture control cables or their attachments failing, leaving aircraft without control over throttle or mixture settings. This problem has been the subject of an NTSB recommendation which would require throttle and mixture controls to move to "an acceptable" setting should the associated linkage become disconnected. Originally, both Part 33 for engines and Part 23 for aircraft were to contain sister requirements, so that new aircraft and new engines would have controls (usually spring-loaded) as described above. The Part 33 proposal was contained in NPRM 92-14, dated 20 October 1992, while the Part 23 proposal was contained in NPRM

CESSNA POSITION, CONTINUED

90-23, dated 03 October 1990. FAR 33, however, never received the new rule, since those involved in the rule update could not decide upon a throttle and/or mixture setting which could be considered safe under all flight conditions, without the use of FADEC(any requirement for FADEC was outside the scope of the proposed rule). FAR 23, however, did adopt the new requirement but changed the content of the rule from that originally proposed(which required that the failure condition must be to a throttle setting which would permit continued safe flight and landing "from any point in the flight envelope of the aircraft," and to a mixture of full rich). In reviewing the Preamble for Amendment 23-43, the changes seemed to be made because the FAA decided that the rule as written was unworkable, since no agreement could be reached on what settings would be acceptable for all flight conditions. Therefore, the essence of the requirement was still adopted by the FAA, with the reason listed in the FAR 23 Preamble: [m]anufacturers have the talent to design a system that will comply with the intent of this regulation" (underline added).

Earlier versions of Cessna piston engine aircraft in general, and the 172 in particular, were CAR 3 aircraft, and were not affected by the regulatory changes brought about by Amendment 23-43. Cessna and its engine manufacturers were free to treat the throttle and mixture failure problem as was deemed appropriate. At one time or another, several of Cessna's aircraft have had spring loading to the full throttle position; however, Cessna removed the springs from certain models, feeling that the lack of a spring would actually be preferable.

If a throttle, spring-loaded to or maintained at any particular setting appropriate for cruise power or higher, were to become disconnected from its cable attachment in flight, engine overspeed would become a distinct danger. This is particularly true during descent, and would be even more probable with an inexperienced or less proficient pilot. The initial evaluation of the problem, and the ensuing increased workload could be distracting enough for even an extremely proficient pilot to cause an unsafe condition. Whereas pilots are routinely trained to handle an engine failure, there are not trained to handle a forced power-on situation.

A similar consideration of an in-flight mixture control linkage failure would show that engine enrichment would occur with a full-rich spring setting, again with a likely attendant workload increase. In such an instance, engine efficiency could significantly decrease, both due to its increased use of fuel, and due to a decrease in power. It is possible that the pilot would not determine the cause of such behavior, and decide to continue flight to his destination in spite of poor engine performance. On a long flight, this decision could lead to a low fuel situation.

Cessna's unpleasant experiences with spring-loaded controls have primarily been two-fold. First, with spring-loaded throttles, the pilot must be careful to always tightly lock the throttle once it has been set, and then to more closely monitor engine operation, since the system's tendency is to creep forward. At least one of Cessna's test pilots has experienced unwanted

CESSNA POSITION, CONTINUED

power advancement during the landing flare with a spring-loaded system, causing a potentially unsafe condition and eventual go-around. In flight, higher-than-selected power settings would be an obvious danger continuously, with a potentially higher number of incidents caused, that solved by, a spring-loaded throttle.

The second case which causes Cessna to avoid spring-loaded controls on the 172R is ground operations. Cessna must consider the safety of the aircraft and people on the ground as well as in the air. Cessna personnel have been placed in a potentially dangerous situation, and Cessna has experienced significant property damage due to a spring-loaded throttle on one of its single-engine aircraft. During work on an aircraft, the engine was inadvertently turned over, and it subsequently started, with the throttle spring-loaded to full power. The aircraft and the building it was in received significant damage which could have otherwise been avoided, although thankfully no personnel were hurt in this case.

With the 172R, Cessna and the FAA agreed that compliance with specific later-amendment paragraphs would not be imposed, except where safety issues were concerned. It is Cessna's contention that throttle linkage failures are not cause by poor or improper design, but rather by improper maintenance of the controls. This position is borne out by the fact that older aircraft are disproportionately susceptible to the problem when compared to newer planes with similar installations. To this end, Cessna believes that improved maintenance in the field is the answer to the problem, not imposed regulations whose benefit is debatable.

For the 172R, the biggest change from earlier versions of the 172 is in the powerplant installation. The 172R receives a Lycoming IO-360-L2A fuel injected engine, whereas earlier versions of the Skyhawk were strictly carburated; however, the operation and mechanical connections of the throttle and fuel mixture controls are still the same. Therefore, particularly in light of the above-listed considerations, the 172R will maintain the same level of operational safety on the redesigned engine installation as that successfully used on earlier Model 172 series airplanes, which the FAA has stated as its goal for the aircraft.

The referenced letter provided Cessna's arguments for removal of FAR 23.1143(g) and 23.1147(b) per Amendment 23-43 as imposed requirements on the Model 172R. Per our previous conversation, it is Cessna's belief that the answer to fuel/mixture control attachment failures is in better maintenance in the field rather than adding springs to the controls. Therefore, in order to "maintain the same level of operational safety on the redesigned [engine installation]...as compared to the earlier Model 172 series airplanes," as was the FAA's stated objective, Cessna desires to leave throttle and mixture control springs off the 172R fuel injection throttle body unit, but to assist the FAA in the development of advisory material which can be used throughout the industry for appropriate guidelines regarding maintenance of throttle and mixture control attachments.

FAA's concurrence and/or input is requested.

FAA POSITION

(1) Regarding compliance with FAR § 23.1093, as amended by Amendment 23-43. Cessna requested FAA concurrence to the closing of the FAA Specific Finding item related to evaluation of engine induction system icing protection for the Model 172R. An equivalent level of safety finding was requested because the induction system does not literally comply with FAR § 23.1093, as amended by Amendment 23-43.

FAA letter dated February 20, 1996, provided concurrence to Cessna's proposed means of compliance with the following conditions:

a. The test article will be conformed.
b. All normal impact tube input to the fuel metering device will be closed off.
c. The test impact tube will be equipped with flexible tubing which is routed to a location in the cockpit for use as a temporary impact tube air reference during takeoff, climb and landing.
d. The air inlet filter will be blocked over 50% of area to simulate icing conditions.
e. At approximately 4,000 feet and normal cruise power conditions, the tube will be blocked off, removing all air source to the impact tube.
f. It must be demonstrated that the engine controls can be adjusted to maintain level flight. Stabilized flight must be possible for at least 30 minutes.
g. The Pilot's Operating Handbook and FAA Approved Airplane Flight Manual must include procedures appropriate for these conditions.

On March 19, 1996, a representative from the FAA Wichita Aircraft Certification Office Flight Test Branch participated in flight tests of a Model 172R with the fuel injector impact tubes closed off, and the engine induction filter blocked over 50% of area. Results showed that the engine could continue to function under various flight conditions without benefit of heat, as required by the referenced regulation. Engine operations under these conditions are conditional to following certain operational procedures.

Cessna provided draft procedures which are proposed to be included in the Model 172R Pilot's Operating Handbook and FAA Approved Airplane Flight Manual. These procedures have been reviewed and found acceptable.

(2) & (3) Regarding compliance with §§ 23.1143(g) and 23.1147(b), as amended by Amendment 23-43. The FAA appreciated Cessna's interest in "maintaining the same level of operational safety on the redesigned (engine installation) as compared to the earlier Model 172 series airplanes." The FAA has reviewed the Cessna Model 172 series production equipped, or not equipped, with throttle and mixture springs and found the following:

FAA POSITION, CONTINUED

Model years 1956 through 1964, carburetor equipped airplanes were manufactured with throttle opening and mixture rich spring devices included as part of the design.

Model years 1965 through 1967, carburetor equipped airplanes were manufactured without throttle opening and mixture rich spring devices included as part of the design.

Model years 1968 through 1986, carburetor equipped airplanes were manufactured with throttle opening and mixture rich spring devices included as part of the design.

Many of the airplane engine controls identified above were also equipped with ball bearing type rod ends. Later equipped airplanes were also produced with pre drilled AN bolts, castellated nuts and cotter pins used to secure the engine controls. These devices were also made mandatory by Airworthiness Directive (AD), issued by the FAA.

The reported problems related to attachment of the engine controls have been reduced since issuance of the ADs. However, Cessna has correctly pointed out that the FAA does not as yet have adequate information available on continued airworthiness of the engine controls. The FAA also recognizes that the primary intent of wording of the referenced Part 23 sections was to account for the expected poor reliability of engine control attachments.

It is determined that Cessna must continue to apply the requirements of §§ 23.1143(g) and 23.1147(b), as amended by Amendment 23-43. Literal compliance with these requirements will involve the addition of spring devices. It is recognized, however, that the original intent of the regulation was to account for the poor reliability of the engine control attachments. If a higher level of reliability can be documented by other means, then the FAA could view this as a means of compliance which is equivalent to literal compliance.

Cessna may, therefore, apply for an equivalent level of safety finding, in lieu of literal compliance to §§ 23.1143(g) and 23.1147(b), as amended by Amendment 23-43. Compensating elements for consideration must include: engine control attachment design features which are not likely to separate in flight; establishment of mandatory inspection intervals; inspection procedures; and replacement criteria.

RECOMMENDATION

(1) Induction Icing. Cessna was found to provide a level of safety equivalent to that envisioned by the referenced regulation. Therefore, Cessna has met the conditions for the grant of an equivalent level of safety with regard to § 23.1093, as amended by Amendment 23-43.

RECOMMENDATION, CONTINUED

(2) & (3) Engine and Mixture Controls. The Cessna design was found to include all the conditional FAA elements. Therefore, Cessna has met the conditions for the grant of an equivalent level of safety with regard to §§ 23.1143(g) and 23.1147(b), as amended by Amendment 23-43.

CONCURRENCE

Original signed by..................

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