Exemption No. 6869

UNITED STATES OF AMERICA
DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION
KANSAS CITY, MISSOURI 64106

In the matter of the petition of RAYTHEON AIRCRAFT COMPANY for exemption from § 23.775(e) of Title 14 Code of Federal Regulations	Regulatory Docket No. CE152

GRANT OF EXEMPTION

By letter dated September 30, 1998, Mr. A. C. Jackson, Raytheon Aircraft Company, Post Office Box 85, Wichita, Kansas 67201-0085 petitioned for an exemption from § 23.775(e), Title 14, Code of Federal Regulations for the Raytheon Model 3000 airplane. The exemption would permit type certification for operation above 25,000 feet, and up to 31,000 feet, of the Raytheon Model 3000 airplane with a windshield and canopy that are not fail-safe designs. The Model 3000 is a pressurized, two-place (tandem seating) airplane powered by a single turboprop engine intended for specialized military training operations as a part 23 airplane in the acrobatic category. The Model 3000 is equipped with ejection seats.

The petitioner requires relief from the following regulation:

> 14 CFR § 23.775(e) requires the fail-safe design of windshields, window panels, and canopies when certification for operation above 25,000 feet is requested.

The petitioner supports the request with the following information:

> (NOTE: The following SCOPE, DISCUSSION, PUBLIC INTEREST and CONCLUSION are verbatim from the petitioner's letter of September 30, 1998. The remaining sections of the petitioner's letter are summarized for brevity.)

"SCOPE

"The Raytheon Model 3000 (JPATS) requirement is to have an FAA certified altitude of 31,000 ft. MSL. All requirements of FAR 23.775, except subparagraph (e), will be met at altitudes above 25,000 ft. MSL up to and including 31,000 ft. MSL. The windshield and canopy structure are manufactured from single ply acrylic as necessitated by requirements for egress, weight, visibility distortion, etc.; therefore, the requirements of FAR 23.775(e) regarding fail-safe above 25,000 ft. MSL cannot be met.

"Raytheon Aircraft, in accordance with FAR 11.25, petitions the FAA Administrator to issue a Permanent Exemption from FAR 23.775(e). It is requested this exemption be included in the Type Certification Basis for this model and its direct derivatives. This request contains information, views, and arguments to support the action sought. Granting this exemption would be in the public interest and would not adversely affect safety by providing a level of safety equal to that provided by the rule from which the exemption is sought.

"With the granting of an exemption to FAR 23.775(e), RAC proposes that the intent of FAR § 23.1527(b) maximum operating altitude would be met and thus the aircraft would not carry the 25,000 ft. limitation requirement of this paragraph. For ease of reference, 23.1527(b) states: (b) A maximum operating altitude limitation of not more than 25,000 feet must be established for pressurized airplanes unless compliance with § 23.775(e) is shown."

BACKGROUND

This section of the petitioner's letter has been summarized for brevity. In this section, the petitioner highlights the Model 3000 windshield and canopy certification activity history.

APPLICABLE AIRWORTHINESS REQUIREMENTS

This section of the petitioner's letter has been summarized for brevity. In this section, the petitioner provides the text of 14 CFR § 23.775, Amendment 23-47 verbatim.

INTENT OF REGULATION

This section of the petitioner's letter has been summarized for brevity. In this section, the petitioner provides the text of the preamble from Amendment 23-7 pertaining to the adoption of 14 CFR § 23.775(e) verbatim.

"DISCUSSION

"From the discussion above, it is clear that FAA's primary concern centers around rapid decompression, especially at higher altitudes (maximum differential pressure) and the hazards associated with such an event. While other portions of the part 23 rules pertain to the structural consequences of such a failure, this particular regulation 23.775(e) pertains to the human factor aspects and consequences of failure such as failure at altitudes where oxygen must be immediately available to the crew and passengers.

"In the unique case of the Model 3000, the differential pressures at 31,000 MSL are not the same as a typical part 23 or even part 25 airplane. This airplane has a significantly lower cabin pressure of 3.6 PSI. In addition, normal operating procedures for the Model 3000 require the crew (and passenger) to don oxygen masks during preflight procedures and wear masks at all times throughout the flight envelope.

"The Raytheon Failure Mode, Effect and Criticality Analysis (FMECA) Report 133E656 accomplished for the Military contract determined the probability of the canopy assembly blowing off for any reason to be approximately 10^{-7}. The probability of the canopy blowing off due to scratches, nicks, chips, etc., which could undermine the structural integrity to the point of canopy loss have not been evaluated from a probability standpoint but, by logic, would be much less than 10^{-7}. Further, the regularly scheduled inspections of the canopy components and a replacement life of the acrylic components as discussed later further reduce such probabilities. Even in the improbable event of canopy loss for any reason, ER 133E656 identifies the pilot action to be reduce speed and reduce altitude to 25,000 feet and indicates the failure effect on the system to be loss of cockpit pressurization, heating, cooling and loss of wind protection. While total canopy loss, though certainly treated as an emergency condition in the Flight Manual, is not a safety concern from a FAR 23.1309 standpoint since it would not qualify as a failure condition that would prevent the continued safe flight and landing of the airplane nor would it qualify as a failure condition that would significantly reduce the capability of the airplane or the ability of the crew to cope with adverse operating conditions.

"Another safety compensating factor that provides support for an Exemption is the strength and integrity of the canopy system as shown by the "bird proof" aspects of the Model 3000 canopy. The transparency system, which includes the windshield and canopy, has successfully passed the impact test of a 4 pound bird at 270 KTAS with no penetration. Furthermore, the transparency system has demonstrated its ability to resist multiple bird impacts of birds up to 4 pounds in weight at 270 KTAS. It is structurally acceptable to return an impacted transparency to service provided a thorough visual inspection reveals no transparency fractures. The test results are documented in the Raytheon Engineering Report 133E430 "Windshield and Canopy Birdstrike Test Result." The birdstrike design analysis is documented in Raytheon Engineering Report 133E424 "Birdstrike Design Analysis Report."

"In addition to the above facts, RAC is prepared to go further to support an Exemption to the applicable FAR, as discussed in the below plan.

"The plan is in two phases and uses a combination of flight testing, ground testing (static and fatigue) and analysis to establish compliance. Phase 1 can be considered as a method for determining a conservative interim replacement life. This value will be established at the time of Certification and be documented in the appropriate manuals. Phase 2 will occur if Phase 1 produces an unacceptably low replacement life and will allow an increase in the safe life figure from Phase 1. The resulting replacement life from Phase 2 will supersede the values in the appropriate manuals established from Phase 1. The plan outline is provided as follows:

"Phase 1

"1. Generate a Finite Element Model (FEM) of the windshield and canopy.

"2. Apply internal pressure conditions to establish analytical stress magnitude throughout the model. A preliminary analysis indicates a stress magnitude due to maximum pressure differential (4.65 psi) of 1135 lb per square inch limit. The 4.65 psi consists of 3.6 + or - .1 and an aerodynamic pressure of +.95.

"3. On the ground static test article (ST-613), install strain gages to three areas on the canopy - one area represents the most highly stressed location in the model and the second and third areas represent the locations where the largest temperature gradients are considered to exist in each of the center and aft canopies. This test is conducted at room temperature.

"4. During ground static tests, monitor and record the strain gage readings for the pressurized condition. This will confirm the low stress level for the maximum pressure differential condition from the FEM.

"5. Correlate readings from 2. and 4. and modify model if required. This gives confidence in the model in predicting stress from pressure.

"6. Install temperature sensors onto flight test article PT-4 at the two locations considered to give the largest temperature gradient (see item 3).

"7. Fly PT-4 at three altitudes and record the stabilized temperature sensor readings. This will provide a data base for determining the temperature gradient cycling for specific flight profiles.

"8. Using the correlated FEM, superimpose the temperature gradient on the stress from maximum delta pressure condition to determine the total stress within an element in the canopy.

"9. Review the JPATS flights and temperature gradient data base to establish an appropriate spectra for JPATS usage.

"10. Establish a spectra for aircraft usage up to 31,000 ft.

"11. Using appropriate fatigue curve data (from Swedlow) and a stress concentration factor of 3 (for a hole), with the data from 8. and the spectra from 9. and 10. above, establish an unfactored fatigue life.

"12. Calculate factored fatigue life (replacement life) by using a scatter factor of 8 (reference AFS 120-73-2, analysis alone). A factor of 8 is used even though the stress and temperature have been correlated with flight and ground test data and an inspection program will be detailed (see below). This higher factor provides conservatism to account for no FEM tuning with temperature gradient.

"13. The lives so established are conservative interim replacement lives, unique to the flight profiles established (one for JPATS and one for operation to 31,000 ft) and will be published in the airworthiness limitations section of the Maintenance Manual(s).

"Note: The preliminary analysis indicates that the aft canopy, being the thinnest, has the highest stress. Although the flight temperature and ground test surveys consider both the center and aft canopies, the replacement life and inspection program of the aft canopy would apply to the windshield and center canopy for additional conservatism.

"Lastly, a combination of regularly scheduled inspections of the components and a replacement life of the acrylic components are an important contribution to ensure continuing structural integrity to that required by FAR 23.775(e). The regularly scheduled inspection program of the windshield and canopy and replacement schedule will be detailed in the Airworthiness Limitation section of the maintenance manual and will thus be of a mandatory nature. These will be inspections for scratches, nicks, chips, etc., which could undermine the structural integrity.

"Phase 2

"This phase will be conducted if unacceptably low lives have been determined from Phase 1.

"14. A special "suitcase type" component test of the canopy assembly will be conducted. The test article will consist of the windshield, center and aft canopies with appropriate hinge and latching mechanism. The test fixture will simulate the boundary members typical of a production configuration to ensure realistic reactions under pressure loading. Maximum delta pressure of 4.65 psi will be applied along with the appropriate temperature gradient across the canopy applicable to an altitude of 31,000 ft. The temperature gradient will remain constant whilst the pressure is continually cycled from 0 to 4.65 psi. Testing will cease when the article is unable to take pressure or until the application of 104,000 cycles whichever comes first. The article will be inspected at regular intervals to monitor any degradation.

"15. The number of cycles so determined will correspond to the unfactored fatigue life for a 31,000 ft flight profile. A scatter factor of 4 will be used to establish the replacement life.

"16. Now that test data exist applicable to pressure with temperature gradient, the FEM can be "tuned", if necessary, for correlation. This allows a reevaluation of fatigue life for the JPATS spectra. Again, a factor of 4 will be used to establish the replacement life.

"17. Both factored replacement lives will replace the interim life from Phase 1."

"PUBLIC INTEREST

"It is in the public interest to grant this exemption both from an economic and a safety aspect. The increased flexibility of the Model 3000 would enhance its prospects, both domestic and internationally. Increased sales increases employment and increased employment stimulates the domestic economy. Likewise, increased international sales improves the U. S. balance of payments."

"CONCLUSION

"Granting this exemption would be in the public interest, and would not adversely affect safety by providing a level of safety equal to that provided by the rule from which the exemption is sought. The various existing compensating factors offered in this paper plus the proposal to conduct additional tasks as identified are offered as evidence supporting these conclusions."

Comments on published petition summary:

A summary of the petition was published, for public comment, in the FEDERAL REGISTER on January 14, 1999. The comment period closed February 4, 1999. No comments were received.

The Federal Aviation Administration's (FAA) analysis is as follows:

To obtain the exemption the petitioner must show, as required by § 11.25(b)(5) of Title 14, Code of Federal Regulations, that: (1) granting the exemption is in the public interest, and (2) granting the exemption will not adversely affect safety, or that a level of safety will be provided that is equal to that provided by the regulation from which exemption is sought.

The FAA has reviewed the petitioner's supporting information and provides the following:

Relevant Policy Actions

A review of our policy files found three relevant policy actions. The first was a request for finding of equivalent level of safety to 14 CFR § 23.775(e) for the Cessna P210R. The FAA denied the request. The FAA noted the pilot and passengers would not be wearing oxygen masks before or at the time of a window or windshield failure and ensuing rapid decompression. The FAA also noted that Cessna had made no provisions to address the varying levels of maintenance that the windshield and windows would receive in a civilian environment.

The second and third were requests for findings of equivalent level of safety to 14 CFR § 23.841 (a), (b)(5), and (b)(6) for the SIAI Marchetti Model S211A and 14 CFR § 23.841(b)(6) for the Raytheon Model 3000. The S211A was a competing design for the JPATS program. Section 23.841, paragraphs (a), (b)(5), and (b)(6) contain requirements for cabin pressurization, including indication and warning systems. The FAA approved both requests. In both approvals, the FAA noted the intended specialized military training mission in which the pilot and passenger must wear oxygen masks throughout the flight envelope as required by the Airplane Flight Manual. The S211A approval required the Airplane Flight Manual and Maintenance Manual to provide adequate procedures to enable safe operation, proper maintenance and servicing of the airplane in a civilian environment. The FAA also noted Raytheon's intent to install a CKPT ALT caution annunciation to alert the pilot(s) if the cockpit altitude exceeds 19,000 feet. A cockpit altitude exceeding 19,000 feet would indicate a failure of the pressurization system at the 31,000 feet certification ceiling.

Determination of Replacement Safe-Life

The FAA does not completely agree with the petitioner's approach for determining the replacement safe-life of the windshield and canopy. The petitioner proposes using a scatter factor of eight for safe-life determined by analysis alone and a scatter factor of four for safe-life determined with the proposed component test. These scatter factors, taken directly from the AFS-120-73-2 report, are applicable to aluminum components only and not the single-ply acrylic material used in the JPATS windshield and canopy. Non-metallic materials typically exhibit greater fatigue life variability than do aluminum alloys.

The FAA interprets 14 CFR § 23.573(a)(6) to require the use of fatigue scatter factors applicable to the acrylic material used in the windshield and canopy. The relevant text from 14 CFR § 23.573(a)(6) is as follows:

§ 23.573 Damage tolerance and fatigue evaluation of structure.

(a) *Composite airframe structure.*

(6) Structural components for which the damage tolerance method is shown to be impractical must be shown by component fatigue tests, or analysis supported by tests, to be able to withstand the repeated loads of variable magnitude expected in service. Sufficient component, subcomponent, element, or coupon tests must be done to establish the fatigue scatter factor and environmental effects. . . .

The petitioner must comply with 14 CFR § 23.573(a)(6) and use fatigue scatter factors based on the petitioner's test data or data provided by the acrylic material supplier. The scatter factor used in computing the replacement safe-life is then:

$$\text{Scatter Factor} = \text{Scatter Factor}_{(\text{Material})} \times \text{Scatter Factor}_{(\text{Analysis})}$$

where $\text{Scatter Factor}_{(\text{Analysis})}$ = 1.0 for full scale spectrum component testing
= 2.0 for analysis only

If the appropriate material data is not available, the petitioner may use guidance provided by the FAA's National Resource Specialist (NRS) for Advanced Composite Materials. The NRS recommends a material scatter factor of 10 for composite materials. The FAA recognizes that acrylic is not a typical composite material and that the recommended composite material scatter factor may be conservative. Advisory Circular AC 20-107A "Composite Aircraft Structure" provides additional guidance for determining the safe-life of composite structure.

Summary

The intent of 14 CFR § 23.775(e) is to protect the pilot and passenger from the hazards of rapid decompression due to failure of the windshield, window panels, or canopy. The FAA agrees that the petitioner will meet a level of safety equal to that provided by 14 CFR § 23.775(e) with all of the following:

(1) The requirement for both pilot and passenger to wear oxygen masks throughout the flight envelope.

(2) Specific pilot training addressing canopy loss.

(3) The establishment of a replacement safe-life for the windshield and canopy.

(4) Regularly scheduled inspections and maintenance of the windshield and canopy.

Granting the exemption should be in the public interest. Granting the exemption will increase the operational flexibility and lower the cost of the airplane, which will increase the domestic and international sales opportunities.

In consideration of the foregoing, I find that a grant of exemption is in the public interest and will not adversely affect safety. Therefore, pursuant to the authority contained in 49 U.S.C. §§ 40113 and 44701, as amended, delegated to me by the Administrator (14 CFR § 11.53), Raytheon Aircraft Company is granted exemption from 14 CFR § 23.775(e), to the extent necessary to permit type certification of the Model 3000 airplane in the part 23 acrobatic category. This exemption is subject to the following conditions and limitations.

Conditions:

1. Raytheon must determine the replacement safe-life of the windshield and canopy using a scatter factor applicable to the acrylic material. The scatter factor must account for the fatigue life variability of the material and the level of component fatigue analysis and test. The scatter factor is given as:

   $$\text{Scatter Factor} = \text{Scatter Factor}_{(\text{Material})} \times \text{Scatter Factor}_{(\text{Analysis})}$$

   where $\text{Scatter Factor}_{(\text{Analysis})}$ = 1.0 for full scale spectrum component testing
   = 2.0 for analysis alone

   and $\text{Scatter Factor}_{(\text{Material})}$ is from the petitioner's or material supplier's data. If the acrylic material data is not available, the petitioner may use a $\text{Scatter Factor}_{(\text{Material})}$ of 10.

2. The Airplane Flight Manual must provide adequate procedures to ensure safe operation in a civil environment, including requirements for wearing of oxygen masks throughout the flight envelope and specific pilot actions in the event of canopy failure.

3. The Airplane Maintenance Manual must provide adequate procedures to allow for proper maintenance and servicing of the windshield and canopy in a civil environment.

Issued in Kansas City, Missouri on March 9, 1999.

Marvin Nuss
Acting Manager
Small Airplane Directorate