DEPARTMENT OF TRANSPORTATION

Federal Aviation Administration

14 CFR Parts 27 and 29

[Docket No. 26352; Notice No. 90-24]

RIN 2120-AC68

Airworthiness Standards; Crash Resistant Fuel Systems in Normal and Transport Category Rotorcraft

AGENCY: Federal Aviation Administration (FAA), DOT.

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: This notice proposes to add comprehensive crash resistant fuel system (CRFS) design and test criteria to the airworthiness standards for normal and transport category rotorcraft. The proposed standards would minimize fuel (and other flammable fluid) spillage near ignition sources, minimize potential ignition sources and, therefore, improve the evacuation time needed for crew and passengers to escape a postcrash fire (PCF). These proposals, if adopted, would minimize the PCF hazard, save lives, and substantially reduce the severe physiological and psychological injuries sustained from postcrash fires in otherwise survivable accidents.

DATES: Comments must be submitted on or before April 3, 1991.

ADDRESSES: Comments on the proposals should be mailed in triplicate to: Federal Aviation Administration, Office of the Chief Counsel, Attn: Rules Docket (AGC-10), Docket No. 26352, 800 Independence Avenue SW., Washington, DC 20591, or delivered in triplicate to room 915G, 800 Independence Avenue SW., Washington, DC. All comments must be marked: Docket No. 26352. Comments may be examined in room 915G between 8:30 a.m. and 5 p.m., weekdays, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: Mr. Mike Mathais, Regulations Group, ASW-111, Rotorcraft Directorate, Aircraft Certification Service, FAA, Fort Worth, Texas 76193-0111, telephone number (817) 624-5123.

SUPPLEMENTARY INFORMATION:

Comments Invited

Interested persons are invited to participate in the making of the proposed rules by submitting such written data, views, or arguments as they may desire. Comments relating to the environmental, energy, federalism, or economic impact that might result from adoption of the proposals contained in this notice are also invited. Substantive comments should be accompanied by cost estimates. Commenters should identify the regulatory docket or notice number and submit comments in triplicate to the Rules Docket address specified above. All communications received on or before the closing date for comments will be considered by the Administrator before taking action on this proposed rulemaking. The proposals contained in this notice may be changed in light of the comments received. All comments received will be available, both before and after the closing date for comments, in the Rules Docket for examination by interested persons. A report summarizing each substantive public contact with FAA personnel concerned with this rulemaking will be filed in the docket. Commenters wishing the FAA to acknowledge receipt of their comments submitted in response to this notice must include a preaddressed, stamped postcard on which the following statement is made: "Comments to Docket No. 26352." The postcard will be date stamped and returned to the commenter.

For convenience, each proposal in this notice is numbered separately. When submitting comments, please refer to the proposals by the proposal number and by the section of the FAR to which they relate.

Availability of NPRM's

Any person may obtain a copy of this NPRM by submitting a request to the FAA, Office of Public Affairs, Attn: Public Inquiry Center, APA-430, 800 Independence Avenue, SW., Washington, DC 20591, or by calling (202) 267-3484. Communications must identify the notice number of this NPRM.

Persons interested in being placed on a mailing list for future NPRM's should request a copy of Advisory Circular No. 11-2A, Notice of Proposed Rulemaking Distribution System, which describes the application procedures.

Background

Statement of Issue

A postcrash fire (PCF) is the number one cause of fatalities and injuries in an otherwise survivable impact resulting from a rotorcraft accident. It is estimated that annually 5 percent of the occupants in survivable rotorcraft accidents are killed or injured by a PCF. These types of fatalities and traumatic injuries would be substantially reduced by adopting the design and test criteria proposed in this notice. Nearly all PCF's are caused by crash-induced fuel leaks that quickly come in contact with ignition sources during or after impact. Current FAA rotorcraft airworthiness standards do not comprehensively address minimizing fuel leaks and potential fuel ignition sources in order to maximize occupant escape time in a survivable crash. The fuel containment and hazard elimination provisions contained in these proposals would, in the majority of cases, give occupants the time necessary to escape a survivable crash before a PCF could become critical. (A crash resistant fuel system, CRFS, would not be expected to prevent all fires; however, a CRFS would, in the majority of impact survivable cases, either prevent a PCF or delay the sudden massive fire, or fireball, long enough to allow the occupants to escape.) These proposed standards have been validated by military safety statistics and their adoption would significantly minimize the PCF hazard and its associated fatalities and injuries.

History

The FAA held its Rotorcraft Regulatory Review Conference in New Orleans, Louisiana, December 10-14, 1979, and invited all interested persons to submit proposals for consideration pursuant to Notice 79-1 (44 FR 3250; January 15, 1979). Several limited-scope CRFS proposals were received at that time and placed on the agenda.

Those original CRFS proposals were based on special provisions from past helicopter certification programs and proposed changes developed within the FAA since formalization of the proposals presented at the Rotorcraft Regulatory Review Conference. This effort was partially incorporated in Amendment 27-23 (53 FR 34198; September 2, 1988). However, due to the potential impact on the regulatory schedule, and the need for further research to foster a comprehensive CRFS rule and associated cost-benefit analysis, the FAA decided to pursue the remaining portions of the original proposals and new, post-conference, CRFS proposals separately. This notice is the result of that decision.

Since no comprehensive requirements for CRFS postcrash fire protection are currently contained in parts 27 and 29, research was conducted (including a survey of historical safety data) to determine the necessity for new CRFS standards. Rotorcraft accidents and incidents that resulted in a PCF were studied to define the statistical nature and magnitude of the hazards. As a result, it was found that nearly 545 occupants per year are involved in survivable rotorcraft accidents, and that

5 percent of the occupants are killed or injured by a PCF.

In addition, studies have shown that several other accidents (over and above the 5 percent that involved PCF-induced injuries or fatalities) resulted in fuel leaks that either did not ignite or were kept from igniting because fire prevention facilities were immediately available.

All of these accidents either had the potential for, or resulted in, burn victims. Typically, survivors of the accidents that involved a PCF experienced immediate severe pain and suffering as well as permanently crippling physiological and psychological injuries from their burns, in addition to impact injuries.

This historical research has shown that the more severe the otherwise survivable accident, the more likely the occurrence of a thermal injury or fatality from PCF. For example, approximately one-half of the severe but partially survivable accidents result in a PCF. This increases the odds of thermal injury or fatality (relative to those of a less severe survivable accident) by a factor of nearly 4 to 1.

Studies have also shown that typical occupant crash survivability factors (e.g., escape time, smoke inhalation and toxic gas exposure time, heat exposure, exit visibility, tolerance to pain, and mental ability) are rapidly and severely reduced by a PCF. As a result, an occupant's ability to escape rapidly diminishes to the point of incapacitation (sometimes termed the escape limit).

Rotorcraft designed to the current regulations may provide an escape time from a PCF of less than 20 seconds. The goal of this proposed rulemaking, for an otherwise survivable crash, is to either prevent a PCF from occurring or, in the most critical survivable case, provide an occupant escape or rescue time of at least 90 seconds. On the average, it is anticipated that several minutes of escape or rescue time from a PCF would be provided.

Based on the preceding information, it is readily apparent why many researchers consider a PCF the number one rotorcraft crash hazard. Clearly, a significant PCF hazard exists that is not comprehensively addressed in either part 27 or 29. This proposal would provide a methodology for minimizing the PCF hazard by adding new CRFS design and test safety criteria to parts 27 and 29.

Further, in the last 10 years, the use of rotorcraft has changed significantly. Many types of small and large rotorcraft are now used in flight operations near potential fuel ignition sources (such as transformers and electrical cables) and in logging or emergency medical service (EMS) operations. These specialized uses are expanding rapidly. In addition, the use of rotorcraft, especially EMS and transport category rotorcraft, has increased dramatically in congested urban areas, and this usage is expected to increase even more sharply in the future. This increased usage adds significantly to the PCF safety concern, because, in congested urban areas, the potential for property damage and loss of life on the ground must be considered in addition to aircraft and occupant losses.

National Transportation Safety Board (NTSB) and other Safety Recommendations

Industry and government safety groups, such as the General Aviation Safety Panel (GASP), the Rotorcraft Airworthiness Project Group (RAPG), and the NTSB, have been advocating CRFS airworthiness standards. Their written recommendations and safety findings have been considered in drafting these proposals.

The GASP panel was formed in 1982 to address areas of concern in aviation safety. One of the areas selected was CRFS. The panel's recommendations (document 18 on the list in the Technical Research section of this preamble) strongly support these proposals.

The major NTSB recommendations (available in the docket for this notice) that have been considered are A–80–90 through A–80–95, dated September 9, 1980, and A–85–69 through A–85–72, dated October 1, 1985. In addition, the NTSB has issued a report titled, "General Aviation Accidents: Postcrash Fires and How to Prevent or Control Them," dated August 28, 1980. All of the information in the NTSB documents strongly supports these proposals.

Technical Research

Because of forecasts for previously unforeseen, increased special use of rotorcraft in hazardous, congested environments and safety group recommendations for creation of CRFS safety regulations, the FAA conducted new technical research. This new research was required to determine the technical feasibility (relative to the current state of the art) for the CRFS level of safety necessary for civil rotorcraft and its technical and economic impact on the public.

This CRFS research centered on the resolution of three major questions:

(1) What is the current state of the art?

(2) Where should the proposed airworthiness standard fall within a state of the art defined essentially by military requirements?

(3) How successful are military CRFS programs, how easily are their safety features adapted, and how are their safety improvements related to similar civil rules?

To resolve these concerns, the following types of documents were reviewed: FAA advisory circulars (AC), military standards, similar foreign airworthiness certification studies, U.S. military survival documentation, FAA research reports, private sector research reports, safety group recommendations, and technical symposium reports and presentation material.

A list of the specific documents, which are available in the document for this notice, follows:

1. AC 21–22, "Injury Criteria for Human Exposure to Impact," dated June 20, 1985.
2. Draft AC 27.562–X, "Dynamic Evaluation of Normal Category Rotorcraft Seats," undated.
3. AC 25.994–1, "Design Considerations to Protect Fuel Systems During A Wheels-Up Landing," dated July 24, 1986.
4. MIL–STD–1290(AV), "Light Fixed-and-Rotary-Wing Aircraft Crashworthiness," dated January 25, 1974.
5. MIL–V–27393 (USAF), "Valve, Safety, Fuel Cell Fitting, Crash Resistant, General Specification For," dated July 12, 1960.
6. MIL–T–27422B, "Military Specification, Tank, Fuel Crash-Resistant, Aircraft," Thru Amendment 1, dated April 13, 1971.
7. British Civil Airworthiness Requirements Paper No. G805, "Crash Landing—Protection of Occupants," Issue 1, dated March 5, 1986.
8. U.S. Army Publication USARTL–TR–79–22A, "Aircraft Crash Survival Design Guide, Volume I—Design Criteria and Checklists," dated December 1980.
9. U.S. Army Publication USARTL–TR–79–22E, "Aircraft Crash Survival Design Guide, Volume V—Aircraft Postcrash Survival," dated January 1980.
10. U.S. Army Publication USAARL Report No. 81–4, "Helicopter Crashworthy Fuel Systems and Their Effectiveness in Preventing Thermal Injury," dated July 1981.
11. FAA Report No. DOT/FAA/CT/85–11, "Analysis of Rotorcraft Crash Dynamics for Development of Improved Crashworthiness Design Criteria," FAA Technical Center Report, dated June 1985.
12. Report No. FAA–ADS–27, "Design, Development and Evaluation of a Crash-

Resistant Fuel System Installation," dated December 1965.

13. American Helicopter Society and Gerogia Institute of Technology National Specialists Meeting Minutes titled, "Crashworthy Design of Rotorcraft," Atlanta Chapter, date April 7–9, 1986.

14. NTSB Special Study, NTSB–AAS–80–2, "General Aviation Accidents; Postcrash Fires and How To Prevent or Control Them," dated August 28, 1980.

15. FAA TSO–C80, "Flexible Fuel and Oil Cell Material," dated August 1, 1963.

16. SAE, Vol. SP–716, Technical Paper 871008, "A Retrofit Crash Protection Installation in Two Models of General Aviation Airplanes," presented at the General Aviation Aircraft Meeting and Exposition, Wichita, Kansas, April 2–30, 1987.

17. Technical Paper, "The Influence of Airplane Size on Crash Design Criteria," presented by Mr. G. Wittlin at the Flight Safety Foundation, Inc. Conference and Workshop on Occupant Safety, October 31–November 3, 1988, in Arlington, VA.

18. GASP report to the Administrator on CRFS, dated December 31, 1987, "Recommendations of the General Aviation Safety Panel Relating to Fire-Resistant Fuel Systems for Small, General Aviation Airplanes with Less than 10 Passenger Seats."

19. FAA–P–8110.3, Report to Congress, "Systems and Techniques for Reducing he Incidence of Post-Crash Fuel System Fires and Explosions," dated December 1988.

20. Amendments 27–25 and 29–29, Occupant Restraint in Normal and Transport Category Rotorcraft (54 FR 47310; November 13, 1989).

As a result of CRFS research, the FAA has concluded that the U.S. military is the pacing activity for CRFS design and test state of the art, that the current state of the art is applicable to civil design, and that current military specifications for CRFS design and test (with some modification of criteria based on FAA-sponsored research results) form a valid basis for these proposals.

Finally, the results of U.S. military CRFS programs were analyzed to determine their success in reducing thermal injuries and deaths and to determine if safety improvement statistics from military programs can be used to predict the success of these proposed civil requirements. A large data base compiled for the U.S. Army PCF Hazard Program (consisting of noncombat and combat data compiled before uniform CRFS fuel system design and test standards existed) was reviewed and compared with a similar military data base accumulated after CRFS standards were generically required by new procurements in 1970.

The noncombat portion of the Army data base was compared with the civil accident data base. Out of 1,000 noncombat survivable rotorcraft accidents without the Army CRFS safety standards employed, there were 133 PCF's. In other words, 13.3 percent of the accidents resulted in a PCF. This is nearly identical to the civil research that showed a PCF in 13.8 percent of all rotorcraft accidents. Therefore, the noncombat military and civil safety data results are comparable.

All Army rotorcraft procured after 1970 incorporate essentially generic CRFS design and test safety standards. Using these generic standards, the Army data base, from 1970 until 1976, accumulated records of 1,258 noncombat accidents in rotorcraft with a CRFS. Also, during this period data were accumulated on 1,160 rotorcraft without a CRFS. These data are statistically sufficient to measure the effect of a generic CRFS design and test standard. Comparison of the statistics for Army rotorcraft with and without a CRFS during this 6-year period shows that thermal fatalities in survivable accidents dropped from 34 for rotorcraft without a CRFS to zero for rotorcraft with a CRFS, and that thermal injuries dropped from 20 for rotorcraft without a CRFS to 5 for rotorcraft with a CRFS. These numbers indicate that military-based CRFS safety provisions are extremely effective in saving lives and substantially minimizing injuries from PCF.

Related Regulatory/Technical Activity

Similar CRFS rulemaking and advisory material are being developed for part 25 and have been published for part 23 (55 FR 7280; February 28, 1990).

Several civil rotorcraft manufacturers have independently recognized the need for a CRFS and offer such systems either as standard equipment or as options, even though not required by regulation. These systems typically employ military-based CRFS designs.

Current Requirements

Parts 27 and 29 do not contain explicit requirements for PCF protection after crashes that result in otherwise survivable impacts. The current regulations do not comprehensively address minimizing fuel leaks and potential fuel ignition sources. Thus, escape time is not now maximized in otherwise surivivable impacts. A comprehensive set of CRFS regulations, such as those proposed herein, would substantially minimize the traumatic injuries and fatalities that result from a PCF.

General Discussion of the Proposals

These proposals are derived, in part, from relevant portions of Army CRFS Design and Test Standards and, in part, from new civil aviation research. However, these proposals differ from analogous Army requirements based on FAA and industry research and engineering experience considering differences in combat and civil crash environments, and other differences such as the wide range of hardware configurations that may be proposed by applicants in the civil environment. For example, use of a flexible liner or bladder as required by the military, though desirable, would not be mandated for civil rotorcraft. Use of spray-on liners, unlined metal, unlined composite, unlined metal-composite combination designs, or any other design would be allowed (in lieu of the military required fuel bladder) if the proposed substantiation criteria were met. Similarly, other military design requirements would be mandated, if it could be shown that the probability of occurrence of the individual failure related to the design requirement in an otherwise survivable crash is extremely improbable or that an equivalent level of safety can be obtained by another acceptable approach.

An otherwise survivable crash, as used in this rulemaking, is defined as one where the survivable human tolerance acceleration limit has not been exceeded in any of the principal rotorcraft axes, where the structure and structural volume surrounding occupants remain sufficiently intact during and after impact to permit survival, and where an item of mass does not become unrestrained and create a hazard to occupants. The term survivable impact has a similar meaning.

Also, it should be noted that some similarities exist between the requirements of §§ 27.863 and 29.863 and proposed new §§ 27.952 and 29.952. Current §§ 27.863 and 29.863 address operational fires (ground and in-flight), and proposed new §§ 27.952 and 29.952 would address PCF's. The same comparison can be made between §§ 27.1337(a)(2) and 29.1337(a)(2) and proposed §§ 29.,952(f)(8) and 29.952(f)(8). The requirements for fire prevention in each area are not entirely, mutually exclusive, and any overlapping requirements may be satisfied simultaneously.

These proposals would apply to all rotocraft fuel systems, including auxiliary propulsion unit (APU) fuel systems, incorporated in a given design.

In general, this notice proposes: (1) explicit design criteria to minimize fuel and flammable fluid spillage and ignition sources; (2) increased crash load factors for fuel cells in and behind occupied areas that are necessary to ensure the static ultimate strength to accommodate both horizontal and vertical impact energy absorption requirements and maintain the basic structural and fuel containment integrity required for survivability; (3) retention of the emergency load factors of § 29.561 and the addition of such factors for § 27.561 for fuel cells in other areas (particularly underfloor fuel cells which, along with the underfloor structure, must absorb the vertical impact energy induced by a survivable crash without leaking fuel and without unduly crushing the occupied cabin volume); and (4) a dynamic vertical impact test to ensure fuel tank vertical energy absorption capability, structural integrity, and fuel containment integrity.

Accordingly, the FAA proposes to add to parts 27 and 29 a set of design and test standards for a CRFS and, thus, minimize the PCF hazard. This is part of an ongoing regulatory program of the FAA to upgrade, improve, and clarify certification standards for rotorcraft. A specific discussion of each proposal follows.

Section 27.561

Section 27.561 would be amended by adding a new paragraph (d) that would require fuselage structure in the area of internal fuel tanks below the passenger floor level to be designed to resist a specific set of load factors identical to those proposed herein for underfloor fuel cells and their attachments in § 27.952(b)(3). This would protect the fuel tanks from ruptures caused by deformation of underfloor structural elements in an otherwise survivable impact. The load factors proposed for § 27.561(d) would be parallel to those in current § 29.561(d).

New § 27.952/§ 29.952

Research has shown that for any rotorcraft crash, civil or military, the primary CRFS safety requirements are proper design standards, vertical velocity energy absorption capability, and horizontal velocity energy absorption capability.

Primary design standard requirements of this rulemaking would be elimination of: (1) fuel and other flammable fluid spillage; and (2) fuel or fuel vapor ignition sources.

The vertical velocity energy absorption capability is the most important dynamic consideration, because energy must typically be absorbed by rotorcraft structure in a short, vertical crushing distance that includes fuel cells typically located beneath the cockpit and passenger compartments. Misting and spilling of fuel from underfloor fuel cells into the cabin volume caused by vertical impact crash loading are common in current designs that are not crash resistant.

Horizontal impact velocities may be relatively high, but typically the energy absorption problem is less severe because of more energy absorbing structure and longer, energy-dissipating skidding distances.

Therefore, paragraph (a) proposes a vertical drop test that would measure vertical impact crash resistance and that would require each fuel cell (or the most critical fuel cell regardless of its construction) to be dropped from a height of 50 feet. This would provide a free-fall impact velocity of approximately 56 ft/s. The proposed 56 ft/s velocity would exceed the 99-percentile survivable impact velocity envelope and would ensure that fuel cell leakage (which could create a PCF) within the envelope is very unlikely. The proposed impact velocity of 56 ft/s (which would result from a 50-foot drop height) has been reduced from the standard military requirement of 65 ft/s based on civil sector studies, civil experience and the recommendation of the GASP committee. Although lesser drop heights have been proposed, the 50-foot drop height has been successfully used for years in substantiating optional CRFS installations. Also, lesser drop heights do not fully account for the range of PCF's involving non-ambulatory occupants seriously injured by the crash impact. The proposed vertical drop test is a simply constructed dynamic test that would require lifting a fuel tank 80 percent full of water (which is equivalent by weight to 100-percent full of fuel), installed in its surrounding fuselage structure (either actual or simulated), to a height of 50 feet and releasing it to freefall on a nondeforming surface such as concrete. This would allow the leak-free integrity and puncture resistance characteristics of the entire assembly to be evaluated as a system. This approach would also allow utilization of any available natural load alleviation credit present in a given design due to the energy absorption of the airframe structure surrounding the fuel cell when that structure is crushed by impact. In addition, this approach would provide realistic testing of potential fuel cell rupture points caused by inherent design features (such as projections), excessive deformations, or local tearout of fittings, joints, or lacings. In some cases, it may be possible to show clearly and conservatively that the surrounding structure (or part of the surrounding structure) would not become a fuel leakage hazard to the fuel cell, itself, during and immediately after a survivable impact. In these cases, any nonhazardous structure may be removed from the drop test configuration. In some cases, only the most critical fuel tank would need to be dropped, thus minimizing the certification burden. This approach would allow flexibility and encourage future designs that minimize survivable impact-induced puncture hazards from the structure that surrounds a fuel cell. The amount of actual and simulated structure to be used in the test (for realism) requires engineering evaluation, hazard analysis, risk assessment, basic engineering analysis, and may also require component or subassembly tests for a proper determination.

Paragraph (b) would provide static load factors for design and stress analysis of fuel tanks and their installations to ensure retention and leak-free structural integrity. The proposed static load factors are necessary because the data defining the crash acceleration pulse are unique for each rotorcraft design. Use of static load factors instead of dynamic acceleration pulses would provide a generic, practical substantiation method that is adequate for simple, concentrated mass retention purposes. All tanks and their installations would be designed and statically analyzed to these load factors.

The proposed fuel cell load factors in paragraph (b)(1) would be identical to the occupant restraint load factors adopted in Amendments 27–25 and 29–29 (54 FR 47310; November 13, 1989) for §§ 27.561(b)(3) and 29.561(b)(3). These increased load factors have been proposed for fuel cells inside the cabin volume to prevent crash-induced fuel cell ballistic hazards and fuel spills (which may cause a PCF) directly on occupants from local structural failures such as rupture or tearouts.

Similarly, a second set of fuel cell load factors are proposed in paragraph (b)(2), which would be identical to the load factors adopted in Amendments 27–25 and 29–29 for §§ 27.561(c) and 29.561(c). These load factors are proposed for fuel tanks mounted above or behind the passenger cabin. These load factors would provide the structural integrity necessary to prevent crash-induced injuries to occupants and to prevent fuel spills.

Finally, the load factors in paragraph (b)(3) are proposed for fuel tanks in areas other than inside, behind, or above the cabin volume. Since many rotorcraft have fuel cells under the cabin floor, these proposed load factors would provide structural protection for underfloor fuel tanks. In addition, the proposed load factors would be identical to the current § 29.561(d) load factors, which have proven to be structurally adequate. The proposal would require standard application of each proposed principal load factor to any type of fuel cell construction and its installation (including attachments).

For some crash resistant, semirigid bladder and flexible liner fuel cell installations, the proposed 50-foot drop test can (when supported by analysis) simultaneously satisfy both the proposed drop test and the downward vertical $(-N_z)$ load factor requirement proposed in paragraph (b)(3) for the fuel cell and its installation. Use of the simultaneous substantiation approach would reduce the certification burden. This approach would also allow significant energy-absorbing structural deformation to occur without adversely crushing the cabin volume or spilling fuel into the occupied cabin.

For applications that seek simultaneous substantiation of the proposed $-N_z$ load factor requirement of paragraph (b)(3) using the proposed drop test, substantiation would still be required (as is currently practiced) for the fuel cell under the loading of the remaining three principal load factors and for the remaining rotorcraft structure under the loading of all four principal load factors. However, structural substantiation could be further simplified by the results of the proposed drop test based on the fuel cell's configuration. For example, a symmetric fuel cell, structurally equivalent in all four directions, could be substantiated to all of the principal load factors proposed in § 29.952(b)(3) by rational analysis based on one successful drop test.

Paragraph (c) would require the use of self-sealing breakaway fuel fittings at all fuel tank-to-fuel line connections, tank-to-tank interconnects, and at other points or junctions where a reasonable probability (as determined by engineering judgment, analysis, or test) of crash-induced hazardous relative motion exists that may cause fuel leakage to an ignition source and create a PCF during an otherwise survivable impact (this relates to a similar requirement in MIL–STD–1290). The only exceptions to the use of self-sealing breakaway couplings would be where other means that provide an equivalent level of safety are employed such as provision of shielded extensible lines (soft hoses covered with braided shielding that have enough slack or stretch built in to absorb relative motion without fuel leakage), provision of motion-absorbing fittings (rotational ball joints or linearly extensible slip joints), or where it can be conclusively shown by a combination of experience, tests, and analysis that the probability of fuel loss to an ignition source in an otherwise survivable crash would be extremely improbable; i.e., 1×10^{-9} or less.

Paragraph (c)(1) would contain the requirement for design features of self-sealing breakaway couplings.

Paragraph (c)(1)(i) would contain the proposed design load conditions necessary to separate a breakaway coupling. These loads would be determined from analysis and tests.

Paragraph (c)(1)(ii) would require that a self-sealing breakaway coupling separate when the minimum breakaway load defined in proposed paragraph (c)(1)(i) is met or exceeded in the local failure modes most likely to occur during an otherwise survivable impact. The primary loading modes (each of which will produce a breakaway load) are determined by analyzing and testing the surrounding structure to determine the probable impact forces, their directions, and the resulting deformations.

Paragraph (c)(1)(iii) would require that all breakaway couplings have a design provision allowing visual inspection by inspectors (or checks by pilots) to determine that the coupling is locked together (leak-free) and remains open such that fuel flow is not shut off during normal operations.

Paragraph (c)(1)(iv) would require that design provisions be present to prevent uncoupling or inadvertent closing due to operational shocks, vibrations, or accelerations. These provisions would depend on the inherent design of the coupling and its installation location.

Paragraph (c)(1)(v) would require that a coupling design not release fuel when the coupling has separated and each end seals off. The amount of fuel spilled is determined by the coupling design and is essentially what is trapped between the seals (in each half of the coupling) after the coupling separates. In most designs this will be less than 8 ounces of fuel per coupling.

Paragraph (c)(2) would require that an individual breakaway coupling (in the case of a single fuel feed line), or a coupling fuel feed system incorporating several couplings (in the case of multiple parallel feed lines each with a single coupling, or of more complex, multitank crossfeed systems that include breakaway couplings), or other equivalent means (stretch hoses, motion absorbing fittings, etc.) be designed, tested, installed, and maintained so that the probability of inadvertent fuel shutoff in flight is 1×10^{-5} or less, as required by current §§ 27.955(a) and 29.955(a). This paragraph would further require that each coupling design meet the requirements of the appropriate fatigue evaluation requirements (including continuing airworthiness requirements) of either § 27.571 or § 29.571 without leaking. The proposed fatigue requirements would not add significantly to the certification burden since the low ratio of working load to crash load would typically result in designs that automatically meet these proposed standards.

Paragraph (c)(3) would require that any equivalent means used in lieu of a breakaway coupling not create an impact-induced load on the fuel line to which it is installed that is greater than 25 to 50 percent of the ultimate load (strength) of the weakest component in the line (load path). This would minimize the occurrence of a line rupture. This paragraph includes a fatigue evaluation requirement similar to that of paragraph (c)(2).

Paragraph (d) would require design and use of frangible or deformable structural attachments for the installation of major fuel system components to other rotorcraft structure where a crash-induced hazardous relative motion may cause rupture and local tearout. The loads proposed in paragraph (d)(1) would be used in conjunction with analysis and tests to determine the maximum amount of deformation required or the local breakaway loads for the attachments. If it can be conclusively determined for an individual component by analysis and test that fuel spillage due to a local structural attachment failure is extremely improbable (1×10^{-9} or less), no further action would be required.

Paragraph (d)(1) would define the impact-induced design load conditions necessary to deform a deformable attachment or to separate a frangible attachment. These loads would be determined from analysis and tests. All possible loading modes (e.g., tension, bending, compression, shear, and combinations thereof) must be considered, and the minimum critical ultimate load (based on the ultimate strength of the weakest component) determined.

Paragraph (d)(2) would require that a frangible or locally deformable attachment perform its intended function when the minimum breakaway or deformation load (as defined in paragraph (d)(1)) is met or exceeded in the local failure modes most likely to occur during an otherwise survivable impact. The primary loading modes (each of which will produce a breakaway or deformation load) that must be considered are determined by analyzing and testing the surrounding structure to determine the probable impact forces and directions. The attachment would be designed to break or deform at the lowest ultimate load determined under paragraph (d)(1).

Paragraph (d)(3) would require that each frangible or locally deformable attachment meet the fatigue requirements of either § 27.571 or § 29.571, as previously discussed for paragraph (c)(2).

Paragraph (e) would require that, as far as practicable, flammable fluids and potential ignition sources be adequately separated and would define several generic types of common ignition sources and potential PCF-producing contact scenarios. The phrase "as far as practicable" means that within the major constraints of the applicant's design (e.g., aerodynamic shape, space, volume, major structural relocation, etc.) the criteria of proposed paragraph (e) must be met to the maximum possible extent (i.e., without causing major redesign). Obviously, the level of practicability would be higher during a new design project than it would be during a project that involves modification of an existing design. This criterion would be accomplished by a thorough design review, by a potential PCF hazard analysis, and by trade studies. The findings would be documented and approved during certification. Any hazardous areas indentified that are not explicitly specified by paragraph (e) must be included and addressed in an equal manner during certification. Engineering evaluation, analysis, and tests would all be required to determine the maximum level of practicability.

Paragraphs (e)(1) and (e)(2) would add design criteria necessary to prevent a PCF by separating flammable fluids from high temperature ignition sources and electrical ignition sources, respectively. Also, any additional PCF hazards identified in a particular design would be documented, addressed equally, and eliminated to the maximum practicable extent during certification.

Paragraph (e)(3) would require that all friction spark, chemical, and electrostatic PCF ignition sources (which relate to a given design or which may be created during impact) be identified and designed out of the system to the maximum practicable extent.

Paragraph (e)(4) would require that, as far as practicable, flammable fluid tanks be separated from occupiable areas.

Paragraph (e)(5) would require that, unless the probability of a fuel leak or spill reaching a potential ignition source or an occupiable area is 1×10^{-9} less in an otherwise survivable impact, a fuel or flammable fluid line be shielded with a drainable fireproof shroud.

Paragraph (e)(6) would require that all firewalls be designed to withstand a survivable impact without losing their sealing ability. Firewall deformation would be allowed, but firewall tear or rupture would not. A survivable impact (unless a better definition is otherwise available from rational analysis with test verification) is defined by the crash load factors of paragraph (b)(1) of this section.

Paragraph (e)(7) would require that drainage holes be located in all flammable fluid tank compartments to prevent accumulation of spilled flammable fluids. Drip fences and troughs would also be required to route spilled fluids away from ignition sources to drainage holes so that accumulation is prevented.

Paragraph (f) would summarize other generic mechanical design criteria. Within the major constraints of the applicant's design (e.g., aerodynamic shape, space, volume, major structural relocation, etc.), the criteria of paragraph (f) would be met to the maximum practicable extent (e.g., without causing a major redesign). This would be accomplished by a thorough design review and potential PCF hazard analysis. The findings would be documented during certification, and PCF hazards of this type that are not specified by this paragraph would be included, addressed equally, and documented during certification. Engineering evaluation, analysis, and tests may all be required to determine the maximum level of practicability.

Paragraph (g) would require rigid or semirigid fuel tank or bladder walls to be both impact and tear resistant. This would prevent a PCF caused by impact-induced rupture and, thus, provide crash resistance. For the purposes of this proposal, a rigid tank or bladder is one that can resist fluid pressure loads as a flat plate in bending. A semirigid tank is one that can resist fluid pressure loads partially as a flat plate in bending and partially as a membrane in tension.

Flexible liners would be exempt from the requirements of paragraph (g) since a flexible liner, unsupported, can resist only pure tension loads acting as a membrane (i.e., it has negligible bending strength). The rigid shell structure that would be required by proposed § 27.967(a)(3), and that is currently required by § 29.967(a)(3), would surround the flexible liner (membrane) and would carry the crash-induced impact and tear loads; however, the flexible liner, in a survivable impact, would only be significantly loaded in tension when the shell structure is penetrated by a sharp object.

Paragraph (h) would state the puncture resistance requirements necessary for puncture resistant flexible liners.

For rigid or semirigid metal tanks, composite tanks (resin matrix), semirigid bladder designs (rubber matrix), metal-composite hybrid designs, and all other tank designs to comply with proposed paragraph (g), analysis, when used, would be supplemented by tests to demonstrate impact and tear resistance. Impact and tear resistance test criteria are included in such documents as MIL-T-27422B. Advisory material would supplement MIL-T-27422B to account for differences in military and civil operations.

Paragraph (h) would require that any type of flexible liner or bladder used in any type of tank construction (integral, hard shell, etc.) meet the strength and puncture resistance requirements of either § 27.963(g) or § 29.963(b), which would include new puncture resistance (strength and penetration energy) requirements. The new puncture resistance requirements would be necessary to meet existing TSO-C80, paragraph 16.0 requirements, using an increased minimum acceptable puncture force of 370 pounds.

Sections 27.963/29.963

Paragraph (f) of § 27.963 would be revised and a new paragraph (e) would be added to § 29.963 to reference the crash resistance requirements of § 27.952 or § 29.952, repectively.

A new paragraph (g) to § 27.963 and a revised paragraph (b) to § 29.963 would require that each flexible fuel tank bladder or liner be approved or shown to be suitable for the particular application and that the liner be certificated to a new puncture resistance standard. Liner or bladder material approval can be an integral part of the certification process or can be shown by the material's prior inclusion in TSO-C80, "Flexible Fuel and Oil Cell Material." Suitability of the installation of the liner or bladder material would be shown on a case-by-case basis as part of each certification application. The proposed new puncture resistance requirement would be a part of the liner or bladder material approval process.

As previously discussed under proposed § 29.952(h), the new puncture resistance requirement would increase the TSO–C80, paragraph 16.0, puncture force minimum value to 370 pounds (current TSO–C80 requirement is 15 pounds) for fuel cell material only. This proposed change would significantly minimize the occurrence of a PCF from fuel spills caused by impact-induced liner or bladder punctures.

New paragraph (h) to § 27.963 would require each integral fuel tank to be inspectable and repairable so that if minor, chronic fuel seepage and weak areas are found, they would be properly maintained and repaired and would not become unintended major fuel spills during a survivable impact. Also, since current § 29.963(d) is identical to proposed § 27.963(h), the proposed change would make parts 27 and 29 parallel.

New § 27.967/Revised § 29.967

A proposed new § 27.967 would be added and would be parallel to the proposed revision to § 29.967. These basic design requirements would ensure that a crash resistant fuel tank installation includes features such as support pads, properly supported liners, protection against minor fuel leakage and fume buildup, and protection against liner wear.

Paragraph (e) of § 29.967 would removed and the requirement would be placed in a proposed paragraph (e) to § 29.963. These changes would make §§ 29.963 and 29.967 parallel with §§ 27.963 and 27.967 and, thus, provide increased standardization.

Sections 27.973/29.973

The proposed revisions to § 27.973 would be parallel with the proposed revisions to § 29.973 that would minimize potential PCF hazards by ensuring that proper crash resistance design requirements are present for fuel tank filler connections and filler caps. Adoption of these proposals would significantly minimize fuel leakage during normal operations and during a survivable impact.

Paragraph (a) of § 29.973 would be revised to include a requirement that all fuel tank filler connections be made crash resistant in accordance with § 29.952(c). Paragraph (a)(3) would be revised to require that all filler caps remain fuel-tight under fuel pressures induced during a survivable impact.

Paragraph (b) of § 29.973 would be revised to require that all transport category rotorcraft (not just Category A as currently required) have a filler cap cover or filler cap that warns when the cap is not fully locked or seated on the filler connection. This change would ensure that a loose filler cap will not allow spilled fuel and cause a PCF in an otherwise survivable impact.

Sections 27.975/29.975

Paragraph (b) of § 27.975 and paragraph (a)(7) of § 29.975 would be revised to require the venting system to be designed to minimize fuel spillage through the vents to an ignition source in the event of a fully or partially inverted attitude following a survivable impact unless the probability of such spillage is $1x10^{-9}$ or less. Since rotor action on impact and other impact dynamics have been found in numerous cases to cause rollovers or other unusual postcrash attitudes, this proposed change would significantly minimize a PCF by minimizing fuel spills through vents to ignition sources when the postcrash attitude of the rotorcraft would allow gravity-induced spills.

Regulatory Evaluation Summary

This section summarizes the full regulatory evaluation prepared by the FAA that provides detailed estimates of the economic consequences of this proposed regulatory action. This summary and the full evaluation quantify costs and benefits, to the extent practicable, to the private sector, consumers, Federal, State, and local governments.

Executive Order 12291, dated February 17, 1981, directs Federal agencies to promulgate new regulations or modify existing regulations only if potential benefits to society for each regulatory change outweigh potential costs. The order also requires the preparation of a Regulatory Impact Analysis of all "major" rules except those responding to emergency situations or other narrowly defined exigencies. A "major" rule is one that is likely to result in an annual effect on the economy of $100 million or more, a major increase in consumer costs, a significant adverse effect on competition, or is highly controversial.

The FAA has determined that this proposal is not "major" as defined in the executive order. Therefore, a full regulatory *analysis,* that includes the identification and evaluation of cost-reducing alternatives to the proposal, has not been prepared. Instead, the agency has prepared a more concise document termed a regulatory *evaluation* that analyzes only this proposal without identifying alternatives. In addition to a summary of the regulatory evaluation, this section also contains an initial regulatory flexibility determination required by the Regulatory Flexibility Act of 1980 (P.L. 96–354) and an international trade impact assessment. If more detailed economic information is desired, the full regulatory evaluation, contained in the docket, can be reviewed.

Evaluation of Benefits

The purpose of this proposed rule is to reduce and eliminate, if possible, thermal fatalities and injuries resulting from postcrash fires. The effect of the proposed rule would be to reduce the overall percentage of fatalities and serious injuries in rotorcraft accidents to approximately the same percentage of fatalities and serious injuries in rotorcraft accidents without postcrash fires.

To evaluate this proposed rule, NTSB accident data from January 1, 1983, to December 31, 1987, were used provided a passenger or a crewmember was seriously injured or killed as a result of the accident, and provided the rotorcraft accident was a crash landing or a collision with an object. These two data filters were used because the proposed rule is primarily intended to reduce or prevent burn injuries and fatalities in severe but survivable accidents. During this 5-year period, there were 295 severe rotorcraft accidents that resulted from crash landings or from collisions with an object. In 143 of these accidents (44 of which involved postcrash fires), none of the occupants survived. There was at least one survivor in the other 152 accidents (19 of which involved postcrash fires).

There was a high fatality rate (77 percent) in accidents that had a postcrash fire which provides strong support for considering the adoption of these proposals. In addition, the percentage of occupants killed or seriously injured was higher in survivable accidents that had a postcrash fire than in survivable accidents that did not have a postcrash fire. In the survivable accidents involving postcrash fires, 23.4 percent of the occupants were killed and 63.0 percent were seriously injured. In survivable accidents without postcrash fires, 15.7 percent of the occupants were killed and 47.6 percent were seriously injured. An effective CRFS would reduce the fatality rate from 23.4 percent to about 15.7 percent and the serious injury rate from 63.0 percent to about 47.6 percent.

There was a noticeable difference between normal (part 27) and transport category (part 29) rotorcraft in the proportion of accidents with postcrash fires and casualties. There seems to be less chance that a severe accident involving part 27 rotorcraft will involve a postcrash fire (19.7 percent ± 4.8 percent, at the 95 percent confidence level) than a severe accident involving a part 29 rotorcraft (35.5 percent ± 17.2 percent, at the 95 percent confidence level). The percentage of fatalities and serious injuries is higher in survivable accidents involving part 27 rotorcraft (71.9 percent ± 4.9 percent, at the 95 percent confidence level) than in survivable accidents involving part 29 rotorcraft (39.5 percent ± 11.0 percent, at the 95 percent level). Because of these two differences, serious rotorcraft accidents were divided into two groups—accidents involving part 27 rotorcraft and accidents involving part 29 rotorcraft.

Most of the accidents involve part 27 rotorcraft. These accidents account for 264 rotorcraft accidents (89.5 percent of the accidents used in this evaluation) and for 553 passengers and crewmembers (83 percent of the people involved in these accidents).

Only a few of the accidents used in this evaluation involve part 29 rotorcraft. These accidents account for 34 (11.5 percent) of the accidents used in this evaluation and for 113 passengers and crewmembers (17 percent of the people involved in these accidents).

Some of the accidents involving postcrash fires in which there were no survivors could have been survivable on impact if there had been no postcrash fire. An effective CRFS would have prevented most of the fatalities in the accidents that were survivable on impact. To properly evaluate the benefits of a CRFS, the number of rotorcraft accidents that were survivable on impact but in which the postcrash fire killed those who survived the impact needs to be estimated. Next, the estimated number of these accidents (and the victims of the accidents) has to be added to the survivable accident category.

A review of a crashworthiness study done for the U.S. Army showed that 50 percent of all rotorcraft accidents with postcrash fires were survivable on impact. This suggests that some of the civilian rotorcraft accidents in which there were no survivors were also survivable on impact. Since there were no survivors in more than 50 percent of the accidents in which there was a postcrash fire, it can be assumed that some of these fatalities might not have occurred had there been no postcrash fire. For part 27 rotorcraft, there were 52 accidents that had a postcrash fire. According to the Army study, 26 of these accidents would have been survivable on impact. Therefore, 10 (36 minus 26) of the 36 postcrash fire accidents in which there were no survivors could have had survivors if there had been no postcrash fire resulting in 20.3 more survivors. Similarly, 5 of the 11 part 29 rotorcraft accidents would have been survivable on impact resulting in 7.5 more survivors.

A second adjustment was also made before the revised postcrash fire casualties were recalculated to reflect the casualty distribution of accidents without postcrash fires. According to the U.S. Army analysis of Army helicopter accidents, crashworthy fuel systems eliminated all burn fatalities and reduced serious burn injuries by 75 percent. Applying this information to civilian rotorcraft accidents, 25 percent of the serious injuries in rotorcraft accidents with postcrash fires would remain as serious burn injuries. Thus, serious burn injuries were reduced by 75 percent. The 25 percent that remain as serious burn injuries have to be netted out to revise the postcrash fire casualty statistics to reflect the casualty distribution of accidents without postcrash fires. In survivable accidents without any postcrash fires involving part 27 rotorcraft, 17.5 percent of the occupants were killed. If crash resistant fuel systems eliminate postcrash fires, then only 17.5 percent of the statistical nonburn casualties (42.8) in survivable accidents that had postcrash fires would have died on impact. Thus, there would have been only 7.5 statistical fatalities (42.8 × 0.175) in these accidents if postcrash fires could be eliminated. The same procedure can be used to estimate serious nonburn injuries, minor injuries, and no injuries. The results of this analysis are shown in the following table.

REDUCTIONS OF CASUALTIES IN SEVERE ROTORCRAFT ACCIDENTS INVOLVING POSTCRASH FIRES

Casualties	Part 27—Rotorcraft			Part 29—Rotorcraft		
	Without CRFS	With CRFS	Difference	Without CRFS	With CRFS	Difference
Fatalities	27.3	7.5	19.8	10.5	1.4	9.1
Serious	18.0	27.0	(9.0)	9.0	7.2	1.8
Minor	1.0	9.4	(8.4)	4.0	11.0	(7.0)
None	1.0	3.4	(2.4)	0.0	3.9	(3.9)
	47.3	47.3		23.5	23.5	

This evaluation shows that a CRFS in civilian rotorcraft would reduce the number of deaths in serious but survivable rotorcraft accidents and increase the number of minor injuries and occupants with no injuries. Serious injuries would increase in accidents involving part 27 rotorcraft, but serious injuries would be reduced in accidents involving part 29 rotorcraft.

To provide the public and government officials with a benchmark comparison of the expected safety benefits of rulemaking actions over an extended period of time with estimated costs in dollars, the FAA currently uses a minimum value of $1.5 million to statistically represent a human fatality avoided. (This is in accordance with guidelines issued by the Office of the Secretary of Transportation.) Serious injuries were estimated to cost $640,000 while minor injuries are estimated to cost $2,300.

Between January 1, 1983, and December 31, 1987, there were an estimated 26 survivable accidents involving part 27 rotorcraft in which there was a postcrash fire, and there were an estimated 7 similar types of accidents involving part 29 rotorcraft. If these rotorcraft had a CRFS installed, the average benefit (reduced costs of casualties per accident) would have been $920,000 per accident involving a normal category rotorcraft and $2,112,000 per accident involving a transport category rotorcraft.

During this 5-year period, there were an average of 9,146 part 27 rotorcraft and 1,238 part 29 rotorcraft in operation in the United States. The probability that a part 27 rotorcraft would be involved in serious (but survivable) accident in which there was a postcrash fire in any given year during that time was estimated to be 0.000569±0.000219 at the 95 percent confidence level. The probability that a part 29 rotorcraft would be involved in a serious (but survivable) accident in which there was a postcrash fire in any given year was estimated to be 0.001131±0.000837 at the 95 percent confidence level. To be conservative, the FAA used 0.000783 (0.000569+0.000219) as its estimate of the annual probability that a part 27 rotorcraft would be in a serious, survivable accident in which there was a postcrash fire. The annual benefits of requiring a CRFS were estimated by multiplying these probabilities by the average reduction in casualty costs resulting from a CRFS. For part 27 rotorcraft, the annual benefits were estimated to be $725 per rotorcraft. For part 29 rotorcraft, these annual benefits were estimated to be $4,157 per rotorcraft.

To compare the annual flow of dollar benefits from a CRFS to its costs, the present value of both the costs and the benefits has to be computed. The present value of the benefits was calculated by first estimating the future annual benefits per rotorcraft per year. This was done by multiplying the estimated reduction in casualty costs per accident (in which there was a postcrash fire) by the probability that the rotorcraft will be involved in a survivable, but severe, accident (in which there was a postcrash fire) in each of the 15 years out in the future. This flow of benefits was then discounted to calculate the present value of these benefits. In this evaluation, a discount rate of 10 percent, as required by Office of Management and Budget (OMB) Circular 94 was used. For part 27 rotorcraft, the estimated present value of the benefits from a CRFS was $5,500. For part 29 rotorcraft, the estimated present value of these benefits was $31,300. A more detailed discussion of the estimation of benefits can be found in the Regulatory Evaluation included in the docket. The FAA believes these estimated benefits are accurate, but the FAA requests comments on these benefit estimates.

Costs

These proposals are likely to cause changes in the design of current fuel systems to make them more crash resistant. The cost of a new fuel system will be dependent on the type of rotorcraft. Generally, costs will be higher for larger rotorcraft than for smaller ones. However, even among rotorcraft of the same size, costs may vary.

There are two basic components to the costs of rotorcraft fuel systems: production costs and operating costs. Production costs include engineering design and development costs, testing and certificating costs, tooling and training costs, and manufacturing costs. The operating costs of the new fuel system are the costs of the additional fuel burned due to the added weight of the improved fuel system plus added maintenance cost, if any.

The engineering design and development costs, the testing and certificating costs, and the tooling and training costs were estimated to be $36,000. These are the costs that would be in addition to those costs associated with the normal process of developing a new rotorcraft based on current regulations. The fuel system is already a major component of rotorcraft design and numerous airworthiness standards are already applicable to its certification. Also, the proposed requirements for a fuel system can be integrated into the overall certification program for a new rotorcraft. Since rotorcraft designers are well aware of the elements of crash resistant design, the incremental design costs of a crash resistant fuel system for a newly designed rotorcraft should not be great. Testing costs cover actual testing and the analysis of test results to satisfy FAA certification requirements. Most of these costs are expected to be for analysis and documentation rather than for actual testing. The only testing required by these proposals is a drop test of each fuel cell to show no loss of a hazardous quantity of fuel under certain crash conditions. Tooling and training costs include expenses for fixtures, tools, and devices to manufacture the fuel system, and the cost of training workers. Each rotorcraft is expected to be in production for 15 years or more, and at least 10 rotorcraft are exepcted to be produced each year. Using 10 percent as the discount rate, the amortized development and certification costs are estimated to be $474 per unit (assuming only 10 rotorcraft are produced each year).

An important element in crash resistant fuel systems is the installation of frangible, self-sealing fittings at key places in the fuel lines. These fittings break away at designed points and at specific stresses, such as those that occur during a survivable crash. The fittings are not intended to break away in hard landings. The FAA estimates that the incremental cost of such fittings is $60 each. The number of fittings will vary from one type of rotorcraft to another. The FAA estimates that a part 27 rotorcraft will use 8 of these fititngs in its fuel system and that a part 29 rotorcraft will use 10 of these fittings. These fittings are estimated to cost $480 for part 27 rotorcraft and $600 for part 29 rotorcraft.

Another element in a crash resistant fuel system is the installation of flexible sections in the fuel lines. These sections are designed to allow the fuel lines to give and to stretch under stress loads caused by survivable crashes. Flexible sections of fuel line are expected to add about $100 to the cost of a fuel system for part 27 rotorcraft and about $150 to the cost of a fuel system for part 29 rotorcraft.

A third major element in a crash resistant fuel system is a strong fuel tank. The costs of this fuel tank are dependent on its design, size, and the number of rotorcraft produced. The average cost of a fuel tank meeting the requirements of this proposal, including installation, is estimated to be $10 per gallon of tank capacity. In this evaluation, part 27 rotorcraft are assumed to have 50-gallon fuel tanks, which would be $500 more expensive as a result of this proposed rule. Part 29 rotorcraft are assumed to have 200-gallon fuel tanks, which would be $2,000 more expensive as a result of this proposed rule.

This proposed rule would increase the acquisition cost of newly certificated part 27 rotorcraft by $1,600 and the acquisition cost of newly certificated part 29 rotorcraft by $3,200. Not only would the proposed rule increase the acquisition costs of newly certificated rotorcraft, it would also increase the operating costs as a result of the increased weight of the fuel system.

The fuel tank accounts for most of the added weight. The FAA estimates that there will be 0.15-pound per gallon weight penalty as a result of fuel tank that is crash resistant. The weight penalty for part 27 rotorcraft is estimated to be 7.5 pounds (50 gal × 0.15 lb/gal) and the weight penalty for part 29 rotorcraft is estimated to be 30 pounds (200 gal × 0.15 lb/gal). The frangible fittings and flexible fuel line section will add an estimated 2 pounds of weight to part 27 rotorcraft and 3 pounds of weight to part 29 rotorcraft. As a result, adopting these proposals would increase the weight of newly certificated part 27 rotorcraft by 9.5 pounds and the weight of newly certificated part 29 rotorcraft by 33 pounds. For part 27 rotorcraft, each extra pound of weight increases annual operating costs by $30.34, and for part 29 rotorcraft, the increase in annual operating costs is $34.58 per extra pound. The estimated increase in annual operating costs of the proposed rule would be $288 for part 27 rotorcraft and $1,141 for part 29 rotorcraft. Over the 15-year expected operating life of a rotorcraft, the present value of this incease in operating costs would be $2,200 for part 27 rotorcraft and $8,700 for part 29 rotorcraft.

The present value of the total cost of this proposed rule for crash resistant fuel systems in newly certificated rotorcraft is $3,700 for part 27 rotorcraft and $11,900 for part 29 rotorcraft. These costs include both the increase in production costs and the increase in operating costs of newly certificated rotorcraft. A more detailed discussion of the cost estimation procedures can be found in the Regulatory Evaluation included in the docket. The FAA believes these estimated costs to be accurate, but the FAA requests comments on the accuracy of these cost estimates.

Benefit-Cost Comparison

The present value of the benefits exceeds the present value of the costs for both part 27 rotorcraft and part 29 rotorcraft. The net benefits per rotorcraft (benefits minus costs) are $1,800 for part 27 rotorcraft and $19,400 for part 29 rotorcraft. This proposed rule would still be cost-beneficial for part 27 rotorcraft even if it is only 67 percent as effective as the U.S. Army's crashworthy fuel systems for rotorcraft. For part 29 rotorcraft, the proposed crash resistant fuel system has to be only 38 percent as effective as the U.S. Army's crashworthy fuel system to be cost-beneficial. The FAA expects that the proposed crash resistant fuel system that would be required by this proposed rule will be more than 67 percent as effective as the U.S. Army's crashworthy fuel system. Therefore, the FAA has determined that these proposals are cost-beneficial.

Trade Impact Statement

The costs imposed by these proposals will not result in a competitive trade disadvantage for U.S. manufacturers in the U.S. market. Foreign manufacturers would have to comply with these proposed regulations as a condition for selling their rotorcraft in the United States and probably will comply with these proposed regulations since the United States is their largest market. In foreign markets, neither U.S. manufacturers nor foreign manufacturers can be required to comply with these proposed standards; therefore, U.S. manufacturers will not be a competitive disadvantage in foreign markets.

Regulatory Flexibility Determination

The Regulatory Flexibility Act (RFA) of 1980 requires Federal agencies to specifically review rules which may have a "significant economic impact on a substantial number of small entities." The FAA has adopted criteria and guidelines for rulemaking officials to apply when determining if a proposed or existing rule has any significant economic impact on a substantial number of small entities.

The FAA small entity standards define a small rotorcraft manufacturer as an independently owned and managed firm having fewer than 75 employees. A substantial number of small entities is one-third of the small entities, provided 11 or more small entities are substantially impacted. There is only one small part 27 rotorcraft manufacturer (Brantly-Hynes Helicopter Inc.) and no small part 29 rotorcraft manufacturers. Accordingly, the proposed regulations would not impact a substantial number of small rotorcraft manufacturers. Small rotorcraft operators are not necessarily impacted by these proposed regulations since they will not be required to purchase rotorcraft certificated under these proposals. They may continue to purchase rotorcraft, either used or new, that were type certificated before these proposals would go into effect.

Accordingly, the FAA has determined that these proposals would not have a significant economic impact on a substantial number of small entities.

Federalism Implications

The regulations proposed herein would not have substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government. Therefore, in accordance with Executive Order 12612, it is determined that this proposal would not have sufficient federalism implications to warrant the preparation of a Federalism Assessment.

Conclusion

For reasons discussed in the preamble, and based on the findings in the Regulatory Flexibility Determination and the International Trade Impact Analysis, the FAA has determined that this proposed regulation is not major under Executive Order 12291. In addition, the FAA certifies that this proposal, if adopted, will not have a significant economic impact, positive or negative, on a substantial number of small entities under the criteria of the Regulatory Flexibility Act. This proposal is considered nonsignificant under DOT Regulatory Policies and Procedures (44 FR 11034; February 26, 1979). An initial regulatory evaluation of the proposal, including a Regulatory Determination and Trade Impact Analysis, has been placed in the docket. A copy may be obtained by contacting the person identified under the section entitled "**FOR FURTHER INFORMATION CONTACT.**"

List of Subjects in 14 CFR Parts 27 and 29

Air transportation, Aircraft, Aviation safety, Rotorcraft, Safety.

The Proposed Amendments

In consideration of the foregoing, the FAA proposes to amend parts 27 and 29 of the Federal Aviation Regulations (14 CFR parts 27 and 29) as follows:

PART 27—AIRWORTHINESS STANDARDS: NORMAL CATEGORY ROTORCRAFT

1. The authority citation for part 27 continues to read as follows:

Authority: 49 U.S.C. 1344, 1354(a), 1355, 1421, 1423, 1425, 1428, 1429, and 1430; 49 U.S.C. 106(g) (Revised Pub. L. 97–449, January 12, 1983).

2. Section 27.561 is amended by adding a new paragraph (d) to read as follows:

§ 27.561 General.

* * * * *

(d) Any fuselage structure in the area of internal fuel tanks below the passenger floor level must be designed to resist the following ultimate inertial factors and loads and to protect the fuel tanks from rupture when those loads are applied to that area:

(i) Upward—1.5g.

(ii) Forward—4.0g.

(iii) Sideward—2.0g.

(iv) Downward—4.0g.

3. A new § 27.952 is added after § 27.951 to read as follows:

§ 27.952 Fuel system crash resistance.

Unless other means acceptable to the Administrator are employed to minimize the hazard of fuel fires to occupants following an otherwise survivable impact (crash landing), the fuel systems must incorporate the design features of this section. These systems must be shown to be capable of sustaining the static and dynamic deceleration loads of this section, considered as ultimate loads acting alone, measured at the system component's center of gravity, without structural damage to system components, fuel tanks, or their attachments that would leak fuel to an ignition source.

(a) *Drop test requirements.* Each tank, or the most critical tank, must be drop-tested as follows:

(1) The drop height must be at least 50 feet.

(2) The drop impact surface must be nondeforming.

(3) The tank must be filled with water to 80 percent of the normal, full capacity.

(4) The tank must be enclosed in a surrounding structure representative of the installation unless it can be established that the surrounding structure is free of projections or other design features likely to contribute to rupture of the tank.

(5) The tank must drop freely and impact in a horizontal position ±10°.

(6) After the drop test, there must be no leakage.

(b) *Fuel tank load factors.* Except for fuel tanks located so that tank rupture with fuel release to either significant ignition sources, such as engines, heaters, and auxiliary power units, or occupants is extremely remote, each fuel tank must be designed and installed to retain its contents under the following ultimate inertial load factors, acting alone.

(1) For fuel tanks in the cabin:

(i) Upward—4g.
(ii) Forward—16g.
(iii) Sideward—8g.
(iv) Downward—20g.

(2) For fuel tanks located above or behind the crew or passenger compartment that, if lossened, could injure an occupant in an emergency landing:

(i) Upward—1.5g.
(ii) Forward—8g.
(iii) Sideward—2g.
(iv) Downward—4g.

(3) For fuel tanks in other areas:

(i) Upward—1.5g.
(ii) Forward—4g.
(iii) Sideward—2g.
(iv) Downward—4g.

(c) *Fuel line self-sealing breakaway couplings.* Self-sealing breakaway couplings must be installed unless hazardous relative motion of fuel system components to each other or to local rotorcraft structure is demonstrated to be extremely improbable or unless other means are provided. The couplings or equivalent devices must be installed at all fuel tank-to-fuel line connections, tank-to-tank interconnects, and at other points in the fuel system where local structural deformation could lead to release to fuel.

(1) The design and construction of self-sealing breakaway couplings must incorporate the following design features:

(i) The load required to separate a breakaway coupling must be between 25 to 50 percent of the minimum ultimate failure load (ultimate strength) of the weakest component in the fluid-carrying line. The separation load must in no case be less than 300 pounds, regardless of the fluid line size.

(ii) A breakaway coupling must separate whenever its ultimate load (as defined in paragraph (c)(1)(i) of this section) is applied in the failure modes most likely to occur.

(iii) All breakaway couplings must incorporate design provisions to visually ascertain that the coupling is locked together (leak-free) and is open during normal installation and service.

(iv) All breakaway couplings must incorporate design provisions to prevent uncoupling or unintended closing due to operational shocks, vibrations, or accelerations.

(v) No breakaway coupling design may allow the release of fuel once the coupling has performed its intended function.

(2) All individual breakaway couplings, coupling fuel feed systems, or equivalent means must be designed, tested, installed, and maintained so that inadvertent fuel shutoff in flight is improbable in accordance with § 27.955(a) and must comply with the fatigue evalution requirements of § 27.571 without leaking.

(3) Alternate, equivalent means to the use of breakaway couplings must not create a survivable impact-induced load on the fuel line to which it is installed greater than 25 to 50 percent of the ultimate load (strength) of the weakest component of the line and must comply with the fatigue requirements of § 27.571 without leaking.

(d) *Frangible or deformable structural attachments.* Unless hazardous relative motion of fuel tanks and fuel system components to local rotorcraft structure is demonstrated to be extremely improbable in an otherwise survivable impact, frangible or locally deformable attachments of fuel tanks and fuel systems components to local rotorcraft structure must be used. The attachment of fuel tanks and fuel systems components to local rotorcraft structure, whether frangible or locally deformable, must be designed such that its separation or relative local deformation will occur without rupture or local tearout of the fuel tank and fuel systems component that will cause fuel leakage. The ultimate strength of frangible or deformable attachments must be as follows:

(1) The load required to separate a frangible attachment from its support structure, or deform a locally deformable attachment relative to its support structure, must be between 25 and 50 percent of the minimum ultimate load (ultimate strength) of the weakest component in the attached system. To prevent inadvertent separation or deformation, the load must be greater than 10 times the normal service loads at the frangible or deformable attachment location. In no case may the load be less than 300 pounds.

(2) A frangible or locally deformable attachment must separate or locally deform as intended whenever its ultimate load (as defined in paragraph (d)(1) of this section) is applied in the modes most likely to occur.

(3) All frangible or locally deformable attachments must comply with the fatigue requirements of § 27.571.

(e) *Separation of flammable fluids and ignition sources.* Flammable fluids must be located as far as practicable from all potential ignition sources. Locations to be avoided must include, but are not limited to, the following:

(1) *High temperature ignition sources.*

(i) Tank fillers or overboard fuel drains must not be located adjacent to engine intakes or exhausts so that flammable vapors could be ingested and ignited.

(ii) Airframe-mounted fuel filters and valves must not be located within the engine compartment or adjacent to engine intakes or exhausts.

(iii) Flammable fluid lines must not be located in any occupiable area unless they are shrouded or otherwise designed to prevent spillage and subsequent ignition during and immediately following a survivable impact.

(iv) Flammable fluid tanks must not be located in or immediately adjacent to engine compartments, engine induction or exhaust areas, heaters, bleed air ducts, hot air-conditioning ducts, or any other hot surface.

(v) Flammable fluid lines must be kept to a minimum in the engine compartment. Fluid lines must be located immediately adjacent to engine exhaust areas, heaters, bleed air ducts, hot air-conditioning ducts, or any other hot surface.

(vi) Flammable fluid lines must not be located where they can readily spill, spray, or mist onto hot surfaces or into engine induction or exhaust areas. These locations must be determined for each aircraft design by considering probable structural deformation hazards in relation to the flammable fluid systems.

(2) *Electrical ignition sources.* (i) Flammable fluid tanks and lines must not be located in electrical compartments.

(ii) Electrical components and wiring must be separated from flammable fluid lines and kept to a minimum in Flammable fluid tank areas.

(iii) Electrical components and wiring must not be located or routed immediately adjacent to flammable fluid lines and vent openings.

(iv) Electrical wiring and equipment that are mandatory in areas where they are immersed in or otherwise directly subjected to flammable fluids and vapors must be hermetically sealed, tested in accordance with § 27.1309, or otherwise protected such that ignition is extremely improbable.

(v) Electrical sensor lines that penetrate fuel tank walls must be protected from abrasion or guillotine cutting during a survivable impact by use of potting, rubber plugs or grommets, or other equivalent means, and must be designed with sufficient local slack, or equivalent means, to prevent both the wires and their protective mountings from being cut by or torn from fuel tank walls by local deformation.

(vi) Electrical wires must be designed with sufficient slack or equivalent means to accommodate structural deformation without creating an ignition source.

(vii) Electrical wires that are subjected to severe local abrasion, cutting, or other damage during a survivable impact must be protected locally by nonconductive shields or shrouds.

(viii) Electrical wires that are not sufficiently separated from heat or ignition sources to avoid potential contact during a survivable impact must be locally shrouded with a nonconductive fireproof shroud.

(3) *Friction spark, chemical, and electrostatic ignition sources.* Flammable fluid lines and tanks must be designed and located to eliminate fuel or fuel vapor ignition from potential mechanical friction spark ignition sources, chemical ignition sources, and electrostatic ignition sources having a high probability of being activated or created during a survivable impact.

(4) *Separation of flammable fluids and occupiable areas.* Flammable fluid tanks must be located as far as practicable from all occupiable areas.

(5) *Fuel line shielding.* Areas of the fuel line system where the probability of spilled flammable fluids reaching potential ignition sources or occupiable areas is greater than extremely improbable (as defined by paragraph (b) of this section) must be shielded with drainable fireproof shrouds.

(6) *Firewalls.* Firewalls must be designed to withstand the load factor requirements of paragraph (b)(1) of this section without losing their sealing ability.

(7) *Flow diverters.* (i) Drainage holes must be located in all flammable fluid tank compartments to prevent the accumulation of spilled flammable fluids within the aircraft.

(ii) Drip fences and drainage troughs must be used to prevent gravity-induced flow of spilled fuels from reaching any ignition sources such as hot engine areas, electrical compartments, or other potential hot spots.

(8) *Fuel drain system.* The fuel drain system and its attachments to the airframe must be designed and constructed, as far as practicable, to be crash resistant.

(f) *Other basic mechanical design criteria.* Fuel tanks, fuel lines, electrical wires, and electrical devices must be designed and constructed, as far as practicable, as follows:

(1) They must be able to withstand a survivable impact.

(2) Fuel and electrical lines and components must be located away from each other, away from probable crash impact areas, and away from areas where structural deformation or large objects (such as engines or transmissions) may, by crushing or penetration, cause fuel spillage or create an electrical ignition source, or both.

(3) Fuel and electrical lines and components must be located separately and away from areas where impact and severing by rotor blades during a survivable impact is probable.

(4) Fuel and electrical lines and components must be in no danger of being punctured or severed during a survivable impact by locally stiff vertical understructure such as a collapsed landing gear strut.

(5) Fuel and electrical lines and components must be routed separately in areas of maximum protection, such as along heavier structural members, and away from areas where significant damage is probable.

(6) Fuel and electrical lines and components running through hazardous areas or directly through structure, such as a bulkhead, must be locally separated and protected from over-extension, severe abrasion and guillotine cutting by frangible panels, suitable clearance, rubber grommets, braided armor shielding (which must be nonconductive for electrical lines), or other equivalent means.

(7) Flammable fluid lines routed directly to instruments, transducers, or other equivalent devices must be crash resistant, in accordance with § 27.1337(a)(2), to minimize leakage in case of line rupture induced during a survivable impact.

(8) Electrical wires routed directly into electrical boxes or instruments must be designed with sufficient local slack and locally routed in the least probable damage direction and zone, or otherwise protected to mimimize the probability of damage-induced arcing.

(9) Fuel lines routed directly into fuel tanks or other fuel system components must be locally routed in the least probable damage direction and zone, or otherwise protected, to minimize the probability of damage-induced fuel leaks.

(g) *Rigid or semirigid fuel tanks.* Rigid or semirigid fuel tank or bladder walls must be impact and tear resistant.

(h) *Flexible fuel tank bladders or liners.* If a flexible bladder or liner of any type is employed in any type of fuel tank construction, the bladder or liner must meet the strength and puncture resistance requirements of § 27.963(g).

4. Section 27.963 is amended by revising paragraph (f) and by adding new paragraphs (g) and (h) to read as follows:

§ 27.963. Fuel tanks: general.

* * * * *

(f) Each fuel tank installed in personnel compartments must be isolated by fumeproof and fuelproof enclosures that are drained and vented to the exterior of the rotorcraft. The design and construction of the enclosures must provide necessary protection for the tank, must be crash resistant during a survivable impact in accordance with § 27.952, and must be adequate to withstand loads and abrasions to be expected in personnel compartments.

(g) Each flexible fuel tank bladder or liner must be approved or shown to be suitable for the particular application and must be puncture resistant. Puncture resistance must be shown by meeting the TSO–C80, paragraph 16.0, requirements using a minimum puncture force of 370 pounds.

(h) Each integral fuel tank must have provisions for inspection and repair of its interior.

5. A new § 27.967 is added to read as follows:

§ 27.967 Fuel tank installation

(a) Each fuel tank must be supported so that tank loads are not concentrated on unsupported tank surfaces. In addition—

(1) There must be pads, if necesary, to prevent chafing between each tank and its supports;

(2) The padding must be nonabsorbent or treated to prevent the absorption of fuel;

(3) If flexible tank liners are used, they must be supported so that they are

not required to withstand fluid loads; and

(4) Each interior surface of tank compartments must be smooth and free of projections that could cause wear of the liner unless—

(i) There are means for protection of the liner at those points; or

(ii) The construction of the liner itself provides such protection.

(b) Any spaces adjacent to tank surfaces must be adequately ventilated to avoid accumulation of fuel or fumes in those spaces due to minor leakage. If the tank is in a sealed compartment, ventilation may be limited to drain holes that prevent clogging and excessive pressure resulting from altitude changes. If flexible tank liners are installed, the venting arrangement for the spaces between the liner and its container must maintain the proper relationship to tank vent pressures for any expected flight condition.

(c) The location of each tank must meet the requirements of § 27.1185 (a) and (c).

(d) No rotorcraft skin immediately adjacent to a major air outlet from the engine compartment may act as the wall of the integral tank.

6. Section 27.973 is revised to read as follows:

§ 27.973 Fuel tank filler connection.

(a) Each fuel tank filler connection must prevent the entrance of fuel into any part of the rotorcraft other than the tank itself during normal operations and must be crash resistant during a survivable impact in accordance with § 27.952(c). In addition—

(1) Each filler must be marked as prescribed in § 27.1557(c)(1);

(2) Each recessed filler connection that can retain any appreciable quantity of fuel must have a drain that discharges clear of the entire rotorcraft; and

(3) Each filler cap must provide a fuel-tight seal under the fluid pressure expected in normal operation and in a survivable impact.

(b) Each filler cap or filler cap cover must warn when the cap is not fully locked or seated on the filler connection.

7. Section 27.975 is amended by revising paragraph (b) to read as follows:

§ 27.975 Fuel tank vents.

* * * * *

(b) The venting system must be designed to minimize spillage of fuel through the vents to an ignition source in the event of a rollover during landing, ground operation, or a survivable impact, unless a rollover is shown to be extremely improbable.

PART 29—AIRWORTHINESS STANDARDS: TRANSPORT CATEGORY ROTORCRAFT

8. The authority citation for part 29 continues to read as follows:

Authority: 49 U.S.C. 1344, 1354(a), 1355, 1421, 1423, 1424, 1425, 1428, 1429, and 1430; 49 U.S.C. 106(g) (Revised Pub. L. 97–449; January 12, 1983).

9. A new § 29.952 is added to read as follows:

§ 29.952 Fuel system crash resistance.

Unless other means acceptable to the Administrator are employed to minimize the hazard of fuel fires to occupants following an otherwise survivable impact (crash landing), the fuel systems must incorporate the design features of this section. These systems must be shown to be capable of sustaining the static and dynamic deceleration loads of this section, considered as ultimate loads acting alone, measured at the system component's center of gravity without structural damage to the system components, fuel tanks, or their attachments that would leak fuel to an ignition source.

(a) *Drop test requirements.* Each tank, or the most critical tank, must be drop-tested as follows:

(1) The drop height must be at least 50 feet.

(2) The drop impact surface must be nondeforming.

(3) The tanks must be filled with water to 80 percent of the normal, full capacity.

(4) The tank must be enclosed in a surrounding structure representative of the installation unless it can be established that the surrounding structure is free of projections or other design features likely to contribute to rupture of the tank.

(5) The tank must drop freely and impact in a horizontal position ±10°.

(6) After the drop test, there must be no leakage.

(b) *Fuel tank load factors.* Except for fuel tanks located so that tank rupture with fuel release to either significant ignition sources, such as engines, heaters, and auxiliary power units, or occupants is extremely remote, each fuel tank must be designed and installed to retain its contents under the following ultimate inertial load factors, acting alone.

(1) For fuel tanks in the cabin:
(i) Upward—4g.
(ii) Forward—16g.
(iii) Sideward—8g.
(iv) Downward—20g.

(2) For fuel tank located above or behind the crew or passenger compartment that, if loosened, could injure an occupant in an emergency landing:
(i) Upward—1.5g.
(ii) Forward—8g.
(iii) Sideward—2g.
(iv) Downward—4g.

(3) For fuel tanks in other areas:
(i) Upward—1.5g.
(ii) Forward—4g.
(iii) Sideward—2g.
(iv) Downward—4g.

(c) *Fuel line self-sealing breakaway couplings.* Self-sealing breakaway couplings must be installed unless hazardous relative motion of fuel system components to each other or to local rotorcraft structure is demonstrated to be extremely improbable or unless other means are provided. The couplings or equivalent devices must be installed at all fuel tank-to-fuel line connections, tank-to-tank interconnects, and at other points in the fuel system where local structural deformation could lead to release of fuel.

(1) The design and construction of self-sealing breakaway couplings must incorporate the following design features:

(i) The load required to separate a breakaway coupling must be between 25 and 50 percent of the minimum ultimate failure load (ultimate strength) of the weakest component in the fluid-carrying line. The separation load must in no case be less than 300 pounds, regardless of the fluid line size.

(ii) A breakaway coupling must separate whenever its ultimate load (as defined in paragraph (c)(1)(i) of this section) is applied in the failure modes most likely to occur.

(iii) All breakaway couplings must incorporate design provisions to visually ascertain that the coupling is locked together (leak-free) and is open during normal installation and service.

(iv) All breakaway couplings must incorporate design provisions to prevent uncoupling or unintended closing due to operational shocks, vibrations, or accelerations.

(v) No breakaway coupling design may allow the release of fuel once the coupling has performed its intended function.

(2) All individual breakaway couplings, coupling fuel feed systems, or equivalent means must be designed, tested, installed, and maintained so inadvertent fuel shutoff in flight is improbable in accordance with § 29.955(a) and must comply with the fatigue evaluation requirements of § 29.571 without leaking.

(3) Alternate, equivalent means to the use of breakaway couplings must not create a survivable impact-induced load

on the fuel line to which it is installed greater than 25 to 50 percent of the ultimate load (strength) of the weakest component in the line and must comply with the fatigue requirements of § 29.571 without leaking.

(d) *Frangible or deformable structural attachments.* Unless hazardous relative motion of fuel tanks and fuel system components to local rotorcraft structure is demonstrated to be extremely improbable in an otherwise survivable impact, frangible or locally deformable attachments of fuel tanks and fuel system components to local rotorcraft structure must be used. The attachment of fuel tanks and fuel system components to local rotorcraft structure, whether frangible or locally deformable, must be designed such that its separation or relative local deformation will occur without rupture or local tearout of the fuel tank or fuel system component that will cause fuel leakage. The ultimate strength of frangible or deformable attachments must be as follows:

(1) The load required to separate a frangible attachment from its support structure, or deform a locally deformable attachment relative to its support structure, must be between 25 and 50 percent of the minimum ultimate load (ultimate strength) of the weakest component in the attached system. To prevent inadvertent separation or deformation, the load must be greater than 10 times the normal service loads at the frangible or deformable attachment location. In no case may the load be less than 300 pounds.

(2) A frangible or locally deformable attachment must separate or locally deform as intended whenever its ultimate load (as defined in paragraph (d)(1) of this section) is applied in the modes most likely to occur.

(3) All frangible or locally deformable attachments must comply with the fatigue requirements of § 29.571.

(e) *Separation of flammable fluids and ignition sources.* Flammable fluids must be located as far as practicable from all potential ignition sources. Locations to be avoided must include, but are not limited to, the following:

(1) *High temperature ignition sources.* (i) Tank fillers or overboard fuel drains must not be located adjacent to engine intakes or exhausts so that flammable vapors could be ingested and ignited.

(ii) Airframe-mounted fuel filters and valves must not be located within the engine compartment or adjacent to engine intakes or exhausts.

(iii) Flammable fluid lines must not be located in any occupiable area unless they are shrouded or otherwise designed to prevent spillage and subsequent ignition during and immediately following a survivable impact.

(iv) Flammable fluid tanks must not be located in or immediately adjacent to engine compartments, engine induction or exhaust areas, heaters, bleed air ducts, hot air-conditioning ducts, or any other hot surface.

(v) Flammable fluid lines must be kept to a minimum in the engine compartment. Fluid lines must not be located immediately adjacent to engine exhaust areas, heaters, bleed air ducts, hot air-conditioning ducts, or any other hot surface.

(vi) Flammable fluids must not be located where they can readily spill, spray, or mist onto hot surfaces or into engine induction or exhaust areas. These locations must be determined for each aircraft design by considering probable structural deformation hazards in relation to the flammable fluid systems.

(2) *Electrical ignition sources.* (i) Flammable fluid tanks and lines must not be located in electrical compartments.

(ii) Electrical components and wiring must be separated from flammable fluid lines and kept to a minimum in flammable fluid tank areas.

(iii) Electrical components and wiring must not be located or routed immediately adjacent to flammable fluid lines and vent openings.

(iv) Electrical wiring and equipment that are mandatory in areas where they are immersed in or otherwise directly subjected to flammable fluids and vapors must be hermetically sealed, tested in accordance with § 29.1309, or otherwise protected such that ignition is extremely improbable.

(v) Electrical sensor lines that penetrate fuel tank walls must be protected from abrasion or guillotine cutting during a survivable impact by use of potting, rubber plugs or grommets, or other equivalent means, and must be designed with sufficient local slack, or equivalent means, to prevent both the wires and their protective mountings from being cut by or torn from fuel tank walls by local deformation.

(vi) Electrical wires must be designed with sufficient slack or equivalent means to accommodate structural deformation without creating an ignition source.

(vii) Electrical wires that are subjected to severe local abrasion, cutting or other damage during a survivable impact must be protected locally by nonconductive shields or shrouds.

(viii) Electrical wires that are not sufficiently separated from heat or ignition sources to avoid potential contact during a survivable impact must be locally shrouded with a nonconductive fireproof shroud.

(3) *Friction spark, chemical, and electrostatic ignition sources.* Flammable fluid lines and tanks must be designed and located to eliminate fuel or fuel vapor ignition from potential mechanical friction spark ignition sources, chemical ignition sources, and electrostatic ignition sources having a high probability of being activated or created during a survivable impact.

(4) *Separation of flammable fluids and occupiable areas.* Flammable fluid tanks must be located as far as practicable from all occupiable areas.

(5) *Fuel line shielding.* Areas of the fuel line system where the probability of spilled flammable fluids reaching potential ignition sources or occupiable areas is greater than extremely improbable (as defined by paragraph (b) of this section) must be shielded with drainable fireproof shrouds.

(6) *Firewalls.* Firewalls must be designed to the load factor requirements of paragraph (b)(1) of this section without losing their sealing ability.

(7) *Flow diverters.* (i) Drainage holes must be located in all flammable fluid tank compartments to prevent the accumulation of spilled flammable fluids within the aircraft.

(ii) Drip fences and drainage troughs must be used to prevent gravity-induced flow of spilled fuels from reaching any ignition sources such as hot engine areas, electrical compartments, or other potential hot spots.

(8) *Fuel drain system.* The fuel drain system and its attachments to the airframe must be designed and constructed, as far as practicable, to be crash resistant.

(f) *Other basic mechanical design criteria.* Fuel tanks, fuel lines, electrical wires, and electrical devices must be designed and constructed, as far as practicable, as follows:

(1) They must be able to withstand a survivable impact.

(2) Fuel and electrical lines and components must be located away from each other, away from probable crash impact areas, and away from areas where structural deformation or large objects (such as engines or transmissions) may, by crushing or penetration, cause fuel spillage, create an electrical ignition source, or both.

(3) Fuel and electrical lines and components must be located separately and away from areas where impact and severing by rotor blades during a survivable impact is probable.

(4) Fuel and electrical lines and components must be in no danger of

being punctured or severed during a survivable impact by locally stiff understructure such as a collapsed landing gear strut.

(5) Fuel and electrical lines and components must be routed separately in areas of maximum protection, such as long heavier structural members, and routed away from areas where significant damage is probable.

(6) Fuel and electrical lines and components running through hazardous areas or directly through structure, such as a bulkhead, must be locally separated or protected from overextension, severe abrasion and guillotine cutting by frangible panels, suitable clearance, rubber grommets, braided armor shielding (which must be nonconductive for electrical lines), or other equivalent means.

(7) Flammable fluid lines routed directly to instruments, transducers, or other equivalent devices must be crash resistant, in accordance with § 29.1337(a)(2), to minimize leakage in case of line rupture induced during a survivable impact.

(8) Electrical wires routed directly into electrical boxes or instruments must be designed with sufficient local slack and locally routed in the least probable damage direction and zone, or otherwise protected to minimize the probability of damage-induced arcing.

(9) Fuel lines routed directly into fuel tanks or other fuel system components must be locally routed in the least probable damage direction and zone, or otherwise protected, to minimize the probability of damage-induced fuel leaks.

(g) *Rigid or semirigid fuel tanks.* Rigid or semirigid fuel tank or bladder walls must be impact and tear resistant.

(h) *Flexible fuel tank bladders or liners.* If a flexible bladder or liner of any type is employed in any type of fuel tank construction, the bladder or liner must meet the strength and puncture resistance requirements of § 29.963(b).

10. Section 29.963 is amended by removing paragraph (b); by redesignating paragraphs (c), (d), and (e) as (b), (c), and (d) respectively; by revising redesignated paragraph (b); and by adding a new paragraph (e) to read as follows:

§ 29.963 Fuel tanks: general.

* * * * *

(b) Each flexible fuel tank bladder or liner must be approved or shown to be suitable for the particular application and must be puncture resistant. Puncture resistance must be shown by meeting the TSO–C80, paragraph 16.0, requirements using a minimum puncture force of 370 pounds.

* * * * *

(e) Each fuel tank installed in personnel compartments must be isolated by fumeproof and fuelproof enclosures that are drained and vented to the exterior of the rotorcraft. The design and construction of the enclosures must provide necessary protection for the tank, must be crash resistant during a survivable impact in accordance with § 29.952, and must be adequate to withstand loads and abrasions to be expected in personnel compartments.

§ 29.967 [Amended]

11. Section 29.967 is amended by removing paragraph (e).

12. Section 29.973 is revised to read as follows:

§ 29.973 Fuel tank filler connection.

(a) Each fuel tank filler connection must prevent the entrance of fuel into any part of the rotorcraft other than the tank itself during normal operations and must be crash resistant during a survivable impact in accordance with § 29.952(c). In addition—

(1) Each filler must be marked as prescribed in § 29.1557(c)(1);

(2) Each recessed filler connection that can retain any appreciable quantity of fuel must have a drain that discharges clear of the entire rotorcraft; and

(3) Each filler cap must provide a fuel-tight seal under the fluid pressure expected in normal operation and in a survivable impact.

(b) Each filler cap or filler cap cover must warn when the cap is not fully locked or seated on the filler connection.

13. Section 29.975 is amended by revising paragraph (a)(7) to read as follows:

§ 29.975 Fuel tank vents and carburetor vapor vents.

(a) * * *

(7) The venting system must be designed to minimize spillage of fuel through the vents to an ignition source in the event of a rollover during landing, ground operations, or a survivable impact, unless a rollover is shown to be extremely improbable.

* * * * *

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