Certification Authorities for Large Transport Aircraft (CATA)

CATA Worklist Item ANAC-001 – Fuel Line installation – Crashworthiness

Date Raised:	Jan 24th /2018		Updated:		Status:	**CLOSED**
Date Revised	June 11th / 2024					
Raised By:	ANAC & Industry Associations					
Contributors:	**ANAC**	**EASA**		**FAA**		**TCCA**
	/"/	/"/		/"/		/"/
Subject:	**Fuel Line Crashworthiness– definition reasonable degree of deformation – 25.993(f)**					
Related Issue(s): (Identify Discussion Paper number, if any)	None					

Description of Issue(s):

(Give a brief background of issue(s)

14 CFR 25.993(f) Amdt. 25-15 and CS 25.993(f) Amdt. 25/0 requires fuel lines located within the fuselage contour to be "designed and installed to allow a reasonable degree of deformation and stretching without leakage."

Post crash fires are responsible for a significant number of fatalities in otherwise survivable accidents in aviation history. In this regard, an important aspect to be considered in aircraft design is fuel line installations.

Interpretation of and guidance to show compliance with this requirement is not harmonized between authorities in terms of:

- The definition of and objective criteria for "a reasonable degree of deformation and stretching without leakage" and survivable crash.

- Variance of acceptable methods of compliance from aircraft program to aircraft program (i.e. No AC or AMC material available specific to this requirement)
    - o Some acceptable methods of compliance have included the incorporation of steel fuel lines with features that allow the lines to elongate and bend without failure, as well as braided steel hoses that provide exceptional impact resistance. Other acceptable methods include guillotine testing in accordance with specific requirements for a specific aircraft via MOC issue paper.

Background:

During a recent certification process (of an airplane with fuselage-mounted podded engines), a concern was raised related to fire due to fuel line rupture post survivable crash landing.

Some applicants considered only deformations and stretching caused by the fuselage being exposed to inflight loads to show compliance to § 25.993(f). However, the requirement scope extends beyond normal or emergency operating loads, with the requirement intent aiming to assure such "reasonable" precautions are taken against fuel leakage during an impact survivable accident. Typical means of compliance for this requirement is a guillotine test with the fuel line pressurized with water. The fuel line after being exposed to an impact of the guillotine, with a minimum displacement that is defined by the aircraft manufacturer according to the aircraft model geometry, should present no signs of leakage.

The authorities have not prescribed objective criteria for determining what constitutes "a reasonable degree of deformation and stretching" that would minimize the hazards in a survivable crash environment. Useful guidance for compliance with § 25.993(f) can be found in Advisory Circular (AC) 25-8 "Auxiliary Fuel System Installation". While AC 25-8 is focused on auxiliary fuel tank installations, it is equally relevant to other fuel system installations. The § 25.993(f) compliance guidance in AC 25-8 Chapter 2, Section 4.a.1.ii reads:

"Consider the crashworthiness characteristics of the line routing. Where possible, interconnect tanks, rigid metal lines and other major fuel system components with flexible lines. Allow sufficient flexible line length to permit some shifting of the components without breaking the lines or connections. The flexibility of the entire fuselage auxiliary fuel line routing should be sufficient to account for fuselage break points. If lines are routed near structural members, the effect of 'guillotine' or slashing action due to a crash landing should be addressed. When routing fuel lines through cabin floor structural lightening holes is necessary, provide sufficient clearance to prevent line severing due to floor deformations on a crash landing. A crashworthiness evaluation report of the auxiliary fuel system installation should be submitted during certification which shows, by analysis or test, that precautions have been taken to minimize the hazards due a survivable crash environment."

By and large, methods of compliance to § 25.993(f) have included incorporation of steel fuel lines that include features that allow the fuel lines to elongate and bend without failure as well as use of braided steel hoses that provide exceptional impact resistance and stretchability.

Points to clarify:
Definition of the "survivable crash" scenarios (Wheels up landing and minor crash criteria are not the intent of requirement)

Fuselage separation/rupture – Is it necessary to assess the flexibility of the fuel feed line in case of the fuselage separation? What is the reasonable degree of deformation and stretching considering this scenario?

Policy – guillotine test.
https://www.faa.gov/lessons_learned/transport_airplane/accidents/N7030U

Proposed Prioritization:
(Per CATA Technical Issues List Prioritization schema)

Question	Answer
1. Is there an active working group related to this issue?	No
2. In which documents are there deviations amongst the authorities?	Deviations are in the published Issue Papers/CRIs
3. Was this issue raised by or at the CMT?	No.
4. What is the level of impact on projects in the future (i.e. minor, major, critical)?	Major; historical issues with domestic certifications and foreign validations have taken up significant time and effort.
5. How many authorities does the issue impact?	Issue impacts all 4 authorities
6. What is the approximate technical complexity of the issue (i.e. low, medium, high)?	Medium complexity.

Recommendation:

CATA to endorse formation of a team comprising SME representatives from the CMT authorities to address the compliance issues identified in this CWI. This SME team will create a guidance paper that describes harmonized acceptable compliance methodologies.

CATA Decision:
(Using CATA criteria for determination of technical issues)

(Phase 1) The CATA accepted this proposed CWI into its work program during its meeting in Brazil March 2018.

SME Discussions:

(Indicate Source: Meeting, Telecon or E-mail)

	Action	Status
FAA sent to the other SME the draft policy.	/"/	/"/
(Phase 2) ANAC SME lead will provide to other SME a document to describe the issues raised during conference call	/"/	/"/

(Phase 3) Team began discussion on the harmonization issues and agreed to hold subsequent meetings on a monthly basis. Team will also consider the best method of decision conveyance.	/"/	/"/
(Phase 3 completion) Initial SME proposition of harmonized practice and implementation method – Target completion date November 2023.	/"/	/"/

SME Recommendation:

(Recommendations from SME Working Group; may contain links and/or embedded documents)

(Phase 4 completion) Finalization of SME proposition and submittal to CATA – Target date Jun 2024.

Final CATA Position:

(Explain agreement, dissent or conclusion on this IP)

The CATA accept the SME team's recommendation and proposed guidance paper. The guidance paper is appended directly to this CWI. The CWI represents an agreement that the guidance paper is harmonized and accepted by all CMT authorities. The CWI form, including the appended paper, document a CMT member authority agreement that member authorities may reference when they are acting as the certificating authority (CA). Following CA endorsement for a particular project, the other CMT member authorities, when acting as validating authority, will accept the approach. If any member-authority under CATA becomes aware of circumstances that make it apparent that following the guidance paper would not result in compliance with the member-authority's applicable airworthiness standards, then the use of this guidance paper is non-binding, and the member-authority may require additional substantiation or design changes as a basis for finding compliance.

Release of CWI:

CATA Representative	Name	Signature	Date
ANAC	Daniel Pessoa Marcelo Leite	Daniel Pessoa Martins Cunha Assinado de forma digital por Daniel Pessoa Martins Cunha DN: dc=br, dc=gov, dc=anac, ou=ANAC, ou=SAR, ou=USUARIOS, cn=Daniel Pessoa Martins Cunha Dados: 2024.07.10 10:00:29 -03'00' Marcelo Henrique Morales Leite Assinado de forma digital por Marcelo Henrique Morales Leite DN: dc=br, dc=gov, dc=anac, ou=ANAC, ou=SAR, ou=USUARIOS, cn=Marcelo Henrique Morales Leite Dados: 2024.07.10 11:34:57 -03'00'	
EASA	Israel Navarro Mathilde Labatut	P.A.	August 2, 2024
FAA	James Wilborn Hung Cao	JAMES E WILBORN Digitally signed by JAMES E WILBORN Date: 2024.08.05 13:32:04 -07'00' Digitally signed by HUNG T CAO Date: 2024.08.10 08:49:40 -04'00'	
TCCA	André Celere Canh Nham	2024-07-30 Nham, Canh Digitally signed by Nham, Canh DN: C=CA, O=GC, OU=TC-TC, CN="Nham, Canh" Reason: I am the author of this document Location: Date: 2024.07.30 11:33:31-04'00' Foxit PDF Editor Version: 13.0.1	

CATA Worklist Item ANAC-001 – Fuel Line installation – Crashworthiness

Regulation (same):

> *ANAC: RBAC 25.993 (f) Each fuel line within the fuselage must be designed and installed to allow a reasonable degree of deformation and stretching without leakage. (Amendment 25-136)*
>
> *EASA: CS 25.993 (f) Each fuel line within the fuselage must be designed and installed to allow a reasonable degree of deformation and stretching without leakage. (Amendment 25)*
>
> *FAA: 14 CFR 25.993 (f) Each fuel line within the fuselage must be designed and installed to allow a reasonable degree of deformation and stretching without leakage. (Amendment 25-15)*
>
> *TCCA: 525.993 (f) Each fuel line within the fuselage must be designed and installed to allow a reasonable degree of deformation and stretching without leakage.*

1. SUBJECT

Fuel Line Crashworthiness

2. STATEMENT OF ISSUE

Fuel lines that are routed in and around the fuselage and are pressurized during airplane operations could, if damaged during an impact survivable crash, result in spillage of fuel that could constitute a fire hazard. The rule does not define the parameters of a survivable crash, or the conditions that fuel lines are expected to withstand without leakage.

3. APPLICABILITY

This document proposes safety objectives and provides guidance on acceptable means of compliance to establish that the fuel lines provide design precautions to prevent fuel leakage and post-crash fire following a survivable crash.

Other related crashworthiness or survivable crash aspects such as occupant survivability, cabin safety and fuel tanks are outside the scope of this document.

The content of this document does not change or create any additional regulatory requirements, nor does it authorize changes in, or permit deviations from, regulatory requirements.

4. BACKGROUND

Amendment 25-15 of the FAA regulations included § 25.993(f) as a result of an accident on a Boeing Model 727 airplane, where fuel lines had been installed in areas where fuel line flexibility had not been required. It was determined the accident was a survivable crash. However, rigid aluminum fuel lines that were routed in an aluminum shroud became severed, releasing fuel under pressure, which was ignited by either sparking generator leads, sparks from the fuselage on the runway, or both. The subsequent fire caused numerous fatalities that could have been prevented if the post-crash fire had not occurred. Prevention of fuel line rupture and fuel leakage is the objective of § 25.993(f) and it states that fuel lines be designed to allow a reasonable degree of deformation and stretching without leakage.

During past certification programs, the "reasonable degree of deformation and stretching" has been misinterpreted as the expansion and contraction that would occur in normal service or in a minor crash landing. However, § 25.993(f) was promulgated to ensure such "reasonable" design precautions are taken to prevent fuel leakage during an impact survivable crash, not just under normal or emergency operating conditions. The intent of the regulation is the elongation and deformations that would occur in a survivable crash.

> Note: When § 25.993(f) was created, installation of fuel lines outside the fuselage was not envisioned. Even though § 25.993(f) explicitly concerns the fuel lines inside the fuselage, applicants should apply the same precautions for fuel lines outside the fuselage contour to avoid having potentially unsafe design features (e.g., FAA § 21.21(b)(2) or EASA §21.A.20(d)(2)). Depending on the authority and specific program context, this may be applied either via § 25.993(f), issue paper or special condition.

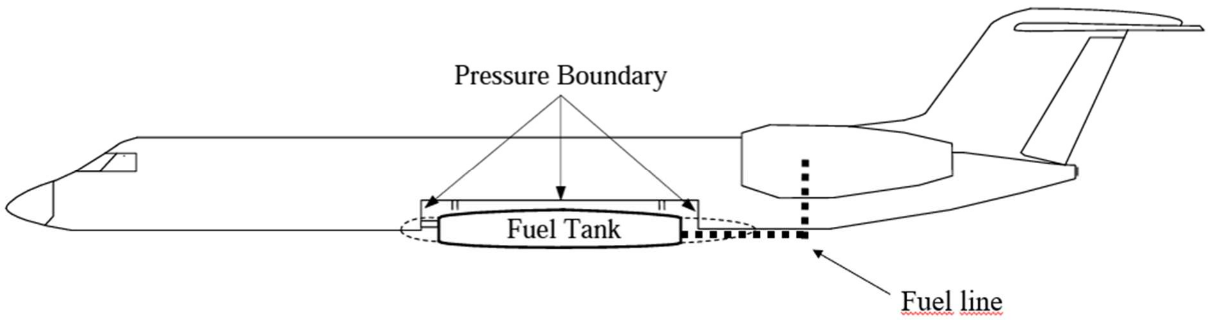

Figure 1 – Diagram of Fuel line outside the Pressure Boundary

Note: Fuel line between fuselage/pylon structure and the engine fuel inlet point on transport aircraft, only with rear-mounted engines, should also be considered.

To apply the rule consistently and equitably to different products of different sizes and design architecture, there must be a standardized approach and criteria that all products can be expected to comply with. The criteria must meet the original intent and expectations of the rule, while not being unnecessarily prescriptive as to preclude or dictate future design innovation, new technologies, or use of materials. The criteria should also be scalable, to ensure appropriate levels of fuel line robustness while remaining practical for the size of product being considered.

Compliance with § 25.993(f) requires determining the envelope case of the deformation and stretching of the fuel lines in order to define the most appropriate means of compliance / test conditions for the fuel line capability demonstration. The aim of this compliance demonstration is not to provide full and comprehensive conditions to meet in a survivable crash for any system but to limit the applicability to the fuel lines.

5. DEFINITIONS

Due to the degree of variability in crash conditions demonstrated by accident data to be survivable, it is impracticable to provide a definitive definition for a survivable crash. The following definitions provide various criteria that should be considered, though not all conditions need be present to ensure an accident is survivable. Considering the difficulty of clearly defining a survivable crash event, the manufacturers should study accidents classified as survivable to develop their analyses. See appendix A for examples of survivable accidents.

Fuel line: rigid or flexible line, which carries the fuel through the fuselage to APU/engine, auxiliary fuel tank, tail tank, rear fuel tank, etc.

NOTE: this definition covers only § 25.993(f) compliance, it is not intended to address fuel line routing in wing.

Survivable Crash: Is defined to be a crash in which: 1) the occupied volumes of the aircraft are maintained (i.e., not crushed or even briefly compromised); and 2) the decelerations along all three primary axes of a restrained occupant remain below the human tolerance for fatality.

Partially Survivable Crash: Crashes in which part of the occupied volume is compromised, and a part remains preserved, or in which a part of the aircraft experiences decelerations beyond human tolerance, are considered to be partially survivable.

Non-survivable Crash: Is defined to be a crash in which either no occupant volume remains anywhere in the aircraft or acceleration loads exceed human tolerance throughout the aircraft. Note that this definition for survivability does not consider the actual injuries experienced in the crash.

NOTE: Survivable Crash, Partially Survivable Crash and Non-survivable crash definitions are not intended to supersede the definition of crash survivability established elsewhere in the regulatory framework.

Retention of Items of Mass: All occupants must be protected during the crash impact event from the release of seats, overhead bins, and other items of mass due to the impact loads and resultant structural deformations of the supporting airframe and floor structures.

Maintenance of Acceptable Loads Experienced by the Occupants: During the crash event the occupant injury criteria thresholds must not be exceeded for the load levels experienced by the occupants.

Maintenance of a Survivable Volume: All areas of the fuselage occupied by passengers for takeoff and landing must provide a survivable volume during the crash impact. Fuselage structural deformation will not result in infringement of the occupant's normal living space so that passenger survivability will not be significantly affected.

Maintenance of the Occupant Egress Paths: After the crash event, the fuselage structure must provide suitable egress paths to evacuate the occupants.

6. RELATED DOCUMENTS.

1) AC 25-8 – "Auxiliary Fuel System Installations," May 2, 1986. https://drs.faa.gov/browse/excelExternalWindow/A3A68E08246D72BB862569B200751F0E.0001

2) DOT/FAA/TC-13/46 – Cherry, R.G.W.: A Study Analyzing the Trends in Accidents and Fatalities in Large Transport Airplanes. Technical Report DOT/FAA/TC-13/46, Federal Aviation Administration. https://www.fire.tc.faa.gov/pdf/TC-13-46.pdf

3) DOT/FAA/TC-17/52 - Labun, L.C. Cress, J.P. Kennedy, D. Study of Transport Aircraft Water Mishap Kinematics and Regional Jet Mishap Kinematics. https://www.tc.faa.gov/its/worldpac/techrpt/tc17-52.pdf

4) DOT/FAA/TC-19/12 – Labun, L.C. Cress, J.P. Kennedy, D. Study of Mishap Kinematics, Damage, and Injury Interactions for Wide-Body and Narrow-Body Transport Aircraft. https://www.tc.faa.gov/its/worldpac/techrpt/tc19-12.pdf

5) Airbus Model A350-900 Special Conditions 25-537-SC – https://www.federalregister.gov/documents/2014/07/25/2014-17574/special-conditions-airbus-a350-900-airplane-crashworthiness-emergency-landing-conditions.

6) Boeing Model 787-8 Special Conditions 25-362-SC – https://www.federalregister.gov/documents/2007/09/26/E7-18942/special-conditions-boeing-model-787-8-airplane-crashworthiness.

7) Learjet Model LJ-200-1A10 Special Conditions 25-528-SC – https://www.federalregister.gov/documents/2014/02/07/2014-02611/special-conditions-learjet-inc-model-lj-200-1a10-airplane-crashworthiness-emergency-landing.

8) Lessons Learned – Boeing Model 727-22 – United Airlines Flight 227, N7030U – https://lessonslearned.faa.gov/ll_main.cfm?TabID=1&LLID=15&faa_keyword=727.

9) Transport Airplane Crashworthiness and Ditching Working Group (TACDWG) Recommendation Report.

   https://www.faa.gov/regulations_policies/rulemaking/committees/documents/media/ARAC-TACDWG_FAA_Report-Final_September20_2018ARAC%20W%20AFA%20DISSENT.pdf

7. ACCEPTABLE MEANS OF COMPLIANCE:

7.1 Survivable crash scenarios

In a survivable accident, it should be assumed that
1) the landing gears may, or may not separate,
2) the engines may, or may not separate,
3) the fuselage can break, separate, and deform, and
4) accidents can occur in widely varying terrain, airplane attitude, hard and soft surfaces, and can impact obstacles such as ditches, fences, and roads.

In addition, some other factors need to be considered in crash survivability outside of compliance with § 25.993(f):

1) Retention of items of mass,
2) maintenance of occupant emergency egress paths,
3) maintenance of acceptable acceleration and loads experienced by the occupants, and
4) maintenance of a survivable volume.

The applicant should define and provide an appropriate rationale for what they consider to be a reasonable degree of deformation and stretching of the fuel line installations based on an evaluation of foreseeable survivable crash scenarios for the type of the aircraft. Considering the original intent of § 25.993(f), authorities have developed the following rationale to characterize crash scenarios where occupant survival may benefit from improved fuel line robustness:

7.1.1 Aircraft Impact attitude:

Crash scenarios where the aircraft impacts terrain with a significant nose up, or nose down pitch attitude, more often result in catastrophic breakup of the fuselage structure. The degree of fuselage breakup is usually to the extent where the survivable volume within the fuselage is significantly compromised. It is unrealistic to expect occupant survival where the survivable volume cannot be maintained. However, impacts with terrain with small or moderate nose up or nose down pitch attitude have shown to be survivable and should be considered.

Crash scenarios where the aircraft initially impacts terrain with its wings not level will result in the low wing contacting the ground first, inducing a violent rate of yaw on the aircraft. These high-speed uncontrolled ground impacts typically result in catastrophic breakup of the fuselage structure to a degree where the survivable volume within the fuselage is significantly compromised. Where sections of fuselage structure remain relatively intact, they would likely become separated by distances greater than could be accommodated by any practical fuel line installation. This scenario would also likely result in catastrophic damage to one or both wing tanks, a large quantity of fuel spillage would occur, rendering the condition of fuel lines located within the fuselage practically irrelevant.

7.1.2 Terrain:

Crash scenarios which take place in mountainous and wooded terrain typically result in significant deconstruction of the fuselage and wing structure, to the point where the survivable volume within the fuselage is no-longer present, and large quantities of fuel spillage from wing tanks would render the condition of fuel lines located within the fuselage practically irrelevant.

Crash scenarios which take place in terrain with ravines, ditches, or raised earth works may include situations where some occupants may survive the dynamic period of impact. However, depending on the size and incline of the terrain, fuselage sections that become detached during the crash sequence are likely to separate from each other by a significant distance. It may be impractical to expect fuselage fuel line designs that remain intact in cases where fuselage sections become completely detached while still in the dynamic period of the crash scenario.

7.1.3 Impact Loads (Descent Rate) for fuselage breakup:

Survivable crash scenarios should consider descent rates capable of producing fuselage loads beyond the ultimate design loads of the applicant's aircraft fuselage. Since the structural properties of each aircraft design will be different, the descent rate to be considered will vary from one applicant´s aircraft to the next and will be dependent on the structural capabilities of each aircraft under consideration. The chosen descent rate must be set at a rate at which the applicant can show their fuselage structure begins to break up. (See reference paragraph 7.2.1). This is necessary so that the applicant can then identify any threats to fuel lines during initial fuselage breakup, which the fuel system design may need to consider when complying with § 25.993(f).

Note: Chapter 1 of Advisory Circular (AC) 25-8, Auxiliary Fuel System Installations, states that "survivable accidents have occurred at vertical descent velocities greater than the 5 feet per second (fps) referenced in § 25.561."

Section 25.993(f) is not tied to a specific scenario since the survivable crash varies significantly by airplane type. Service experience has shown the airframe can largely stay intact at high vertical impact loads, beyond any design loads, allowing passengers to evacuate. Authorities recently applied, on certain airplanes, a crash scenario evaluation of typical fuselage sections at descent rates up to 30 fps based on FAA and industry data that shows there is a high occupant survival rate at these vertical descent rates. (See references 5, 6 and 7).

7.1.4 Runway Overrun:

During overrun events, the main landing gears and wing mounted engines are designed to disengage from the aircraft. This situation will result in conditions of a direct contact of the whole lower portion of the fuselage structure with the ground and, consequently, it leads to a less critical fuel line clearance necessity since a smaller deformation angle is required when compared to conditions where the fuselage is also broken but the main landing gears were still engaged after the overrun event. In addition, the worst damage on the aircraft will occur on the region that first hit an obstacle, which is subjected to variations that do not allow the establishment of an objective criteria. Therefore, the applicant must focus on vertical landing crash scenarios. However, runway overruns may occur after initial impact and such events should therefore be included when evaluating foreseeable survivable crash scenarios for the type of the aircraft.

7.1.5 Other Crash scenarios applicable:

The wide range and combinations of crash scenarios, and the different effects each scenario may have on aircraft structure and occupants, make it impractical to define all-encompassing design requirements for fuel lines located in fuselage structure. The applicant should concentrate on crash scenarios for which supporting accident data shows occupants surviving the dynamic period of impact with terrain, and for which it may be practical to analyse and predict the way in which a given aircraft structure might behave. Specifically, the scenario applicants must consider should involve wings level forward flight, high rate of descent, and contact with relatively flat and level terrain resulting in fuselage breakup.

> Note: The applicant is not expected to consider continued movement of separated fuselage sections after separation, other than settlement.

During this scenario the applicant must also consider cases with landing gears in both the extended and retracted positions at the moment of ground impact, as well as consideration of cases with or without loss of engines due to ground impact. The intent is to define accident characteristics that would have the worst effect on the particular aircraft.

7.2 SAFETY ANALYSIS.

To assess compliance with the rule, applicants must conduct an analysis of their aircraft's structure and fuel system behaviour in a survivable crash scenario. This includes demonstrating that the fuel lines can withstand deformation and stretching without leaking. The depth of the analysis depends on, for example, the factors such as the aircraft's size, the installation of the fuel lines, the propulsion's location, and whether the assessment is for a new type certificate (TC) or a modification.

7.2.1 Aircraft Structural Analysis:

The applicant should perform a structural analysis of their aircraft to show where and how the fuselage is expected to break up, identifying the critical cross-sections of the fuselage in a survivable crash accident. An analysis may range from a simple assessment to a complex aircraft structural analysis. Survivable accidents data (see examples in appendix A) shows that it is possible for a fuselage to break up at multiple places, therefore the analysis should identify all critical fuselage cross-sections where there are fuel lines. For the purpose of this analysis the ground may assumed to be rigid.

The analysis must consider ground impact with landing gear in both extended and retracted positions, as well as considering possible loss of engines due to ground impact, and characterise to the greatest extent possible, the way in which each section of fuselage settles on the ground after breakup. If the applicant can clearly show by analysis that the loads required to begin fuselage breakup are such that the landing gear will collapse to the retracted position, or become detached from the aircraft before the point of fuselage breakup, then the applicant need only consider the landing gear retracted condition in their analysis of the fuselage breakup and settlement. At each critical fuselage cross-section expected to break, the analysis should determine any threats and effects to fuel lines transiting those areas.

The applicant must quantify to the greatest extent practical, the deflections and elongations, expansion and contraction of fuselage structure, as well as identify any areas where structure may contact fuel lines, particularly where contact may exert shearing or pinching actions on fuel lines.

7.2.2 Systems analysis of Fuel System Installation:

The fuel system installation should be assessed by performing an analysis, to quantify the effects on fuel lines of the fuselage structural deformation and break up defined in the aircraft structural analysis. The applicant must determine how each fuel line is able to distribute deflections and elongation, or whether they become detached, allowing the fuel line to accommodate additional deflection or elongation. This analysis should also determine any effects that other systems, airframe structure or other equipment may have, whether contact between them and the fuel lines can influence fuel line deflection or elongation by restricting fuel line movement, or whether they have the potential to cause other damage that may result in fuel leakage (e.g. when routing fuel line through cabin floor structural lightening holes, it is necessary to provide sufficient clearance to prevent fuel line severing due to floor deformations on a crash landing).

Flexible fuel hoses provide a more positive means to preclude fuel line ruptures and leaks and are considered one example of an acceptable design precaution. Rigid fuel lines may present more risk to demonstrate compliance with § 25.993(f). The applicant may be required to conduct tests, to demonstrate the fuel lines can withstand, without leakage, the deformation, elongation, and any other effects (such as shear action) established through analysis. The need for testing, and the details of the test definition should be agreed to by the authority.

The applicant must account for each threat identified in the analysis and justify how the defined test accurately reflects the threat. The tests should include production fuel lines, installed in the same manner as they would be on the aircraft, using production hardware. Deflections and elongations should be initiated in the same location, and allowed to propagate over the same length of fuel line as indicated in the analysis and must be induced and influenced in a similar way.

Where analysis indicates structure, systems, or components may be likely to come close to, or contact fuel lines during an event, such structure or other items may need to be included in the test. This is particularly important where a fuel line may become trapped or pinched, potentially restricting the fuel lines ability to spread deflection or elongation effects along its length.

> Note: Special attention must be given to aluminum fuel lines as they were the scope of an Airworthiness Directive associated with the Model 727 airplane accident that resulted in the § 25.993(f) promulgation.

8. Method of Compliance

8.1 Guillotine Test Details.

Mount the fuel line in a test fixture simulating the airplane configuration. The fixture should restrain the fuel line consistent with the airplane installation, including any fuel line couplings, shrouds, clamps, or other fuel line fittings which form part of the fuel line design configuration.

Since the routing of the fuel line is susceptible to direct impact from a separated landing gear, as well as stretching, cracking and cutting action during fuselage deformation and/or separation, the applicant should provide an analysis of their design to support testing the critical configuration, or propose testing multiple configurations.

The fuel line should be pressurized with water to the maximum deadhead pressure of the associated fuel supply system. Maintain the pressure throughout the test to further simulate the fuel feed system operation.

The guillotine specification and installation should be agreed with the Authority. An acceptable example may be: A guillotine, consisting of a 1/8-inch steel blade and a total weight of 76 lbs., should be dropped from a height of 37 feet (~ 34fts) and guided to impact the exposed fuel line or hose at the most critical point.[1]

There should be no leaks during or following the test.

A reasonable degree of deformation and stretching (based on results of analysis) may be demonstrated by a minimum fuel line deflection of 24 inches to fuel line installation approximately 12 feet in length, or 10 inches to fuel line installation approximately 6 feet in length, without experiencing leakage.

An example of the test set up is shown in Figure 2.

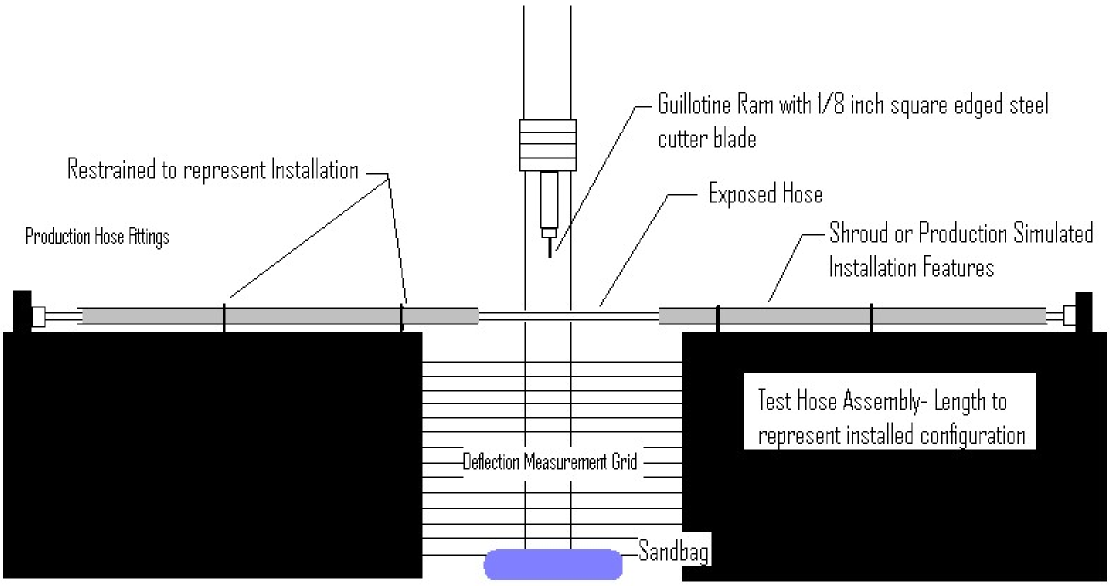

Figure 2. Fuel Line Guillotine Test Setup

8.2 Other methods of compliance

Based on the results of the analyses another Method of Compliance may be proposed for acceptance by the Certification Authority.

[1] United 727 Accident and Guillotine Test Animation https://lessonslearned.faa.gov/ll_main.cfm?TabID=1&LLID=15&LLTypeID=2#null

APPENDIX A – Examples of Survivable Accident Scenarios

The following information provides, examples of accidents resulting in fuselage breaks.

1. On 14 September 1999, Boeing 757-200 G-BYAG at Girona Airport[2].

Crew:	Fatalities: 0 / Occupants: 9
Passengers:	Fatalities: 1 / Occupants: 236
Total:	Fatalities: 1 / Occupants: 245

The aircraft made an approach and landing at Girona Airport, Spain, at night through heavy thunderstorms with rain. At a late stage of the approach, the airfield lighting failed for a few seconds. The aircraft touched down hard simultaneously on the nose and mainwheels and bounced. A second harder touchdown on the nosewheel displaced the nose landing gear and its support structure. Resultant aircraft systems damage caused the loss of virtually all electrical power, interference with controls and uncommanded forward thrust increase.

The aircraft ran off the side of the runway at high speed around 1,000 metres after the second touchdown. After crossing a number of obstacles, it landed heavily in a field outside the airfield boundary and came to rest after travelling almost 1,900 metres from the second touchdown. The fuselage had been fractured in two places and there was considerable disruption to the cabin. There was no fire.

2. On 20 June 2012 at 1200 LT Type of Aircraft: Grumman G-159 Gulfstream GI Operator: International Trans Air Business Registration 9Q-CIT

Crew:	Fatalities: 0 / Occupants: 2
Passengers:	Fatalities: 0 / Occupants: 3
Total:	Fatalities: 0 / Occupants: 5

Following an uneventful flight from Lubumbashi-Lueno Airport, the crew made a steep approach and a hard landing. Aircraft bounced and climbed to a height of 20 feet, landed again and went out of control. It veered off the runway to the left, hit a rocky embankment and lost its nose gear before coming to rest, broken in several pieces. All five occupants escaped uninjured while the airplane was destroyed. According to Congolese reports, it appears that crew made a sharp turn late on final to join the runway and the angle of descent was excessive during the last segment. Aircraft landed hard and bounced before becoming out of control.

https://www.baaa-acro.com/crash/crash-grumman-g-159-gulfstream-gi-pweto

3. On 15 November 1975, Fokker F28 in Concordia, Argentina (LV-LOB)

Crew:	Fatalities: 0 / Occupants: 4
Passengers:	Fatalities: 0 / Occupants: 56
Total:	Fatalities: 0 / Occupants: 60

[2] CIAIAC Technical Report A-054/1999

The left wingtip struck a tree 4 km short of runway 21 during a visual VOR approach. The aircraft contacted the ground, shearing off the nose- and main gear. The nose and right wing truncated a large tree, before coming to rest.

4. On 22 December 2009, an American Airlines Boeing 737-800[3]

Crew: Fatalities: 0 / Occupants: 6
Passengers: Fatalities: 0 / Occupants: 148
Total: Fatalities: 0 / Occupants: 154

Flight 331 overran the runway on landing at Kingston in poor weather. The plane continued on the ground outside the airport perimeter and broke apart on the beach, causing injuries.

Factors contributing to the crash include the speed of the aircraft upon landing and the plane touching down more than 4,000 feet from the start of the runway. Contributing factors included American Airlines' failure to provide training on tailwind landings, and the FAA's failure to implement the NTSB's previous recommendation, following a previous fatal accident involving a tailwind landing attempt, that the FAA require commercial operators to train flight crews on tailwind landings.

5. On 28 December 1998, Embraer EMB-145ER[4]

Crew: Fatalities: 0 / Occupants: 4
Passengers: Fatalities: 0 / Occupants: 36
Total: Fatalities: 0 / Occupants: 40

Flight 310 arrived at Curitiba following a flight from Rio de Janeiro and São Paulo. Instrument meteorological conditions existed, with a cloud base at 300 feet. The Embraer made a heavy landing on runway 15 causing extensive structural damage. The crew managed to steer the aircraft onto taxiway India; an emergency evacuation was then ordered.

[3] Jamaica Civil Aviation Authority Accident Report Number JA-2009-09, December 22, 2009
[4] http://sistema.cenipa.aer.mil.br/cenipa/paginas/relatorios/rf/pt/pt_spe_28_12_98.pdf