b. The fuel and its vapours in flammable concentrations will not pass close to parts of the aeroplane which will produce electrical discharges capable of igniting fuel/air mixtures.

NOTE: Electrical discharges may, in addition to direct lightning strikes, be caused by corona and streamer formation in the vicinity of thunderstorms.

3 The fuel system of the aeroplane should be so designed that the passage of lightning discharges through the main aeroplane structure will not produce, by the process of conduction or induction, such potential differences as will cause electrical sparking through areas where there may be flammable vapours.

NOTE: For aeroplanes of conventional shape, an acceptable method of complying with CS 25.954 is given in FAA Advisory Circular AC20-53A – 'Protection of Aircraft Fuel Systems against Fuel Vapour Ignition due to Lightning'. For aeroplanes of non-conventional shape, re-definition of the zones may be necessary.

AMC 25.955(a)(4)
Fuel Flow

The word 'blocked' should be interpreted to mean 'with the moving parts fixed in the position for maximum pressure drop'.

AMC 25.963(a)
Fuel Tanks: General

Precautions should be taken against the possibility of corrosion resulting from microbiological contamination of fuel.

AMC 25.963(d)
Fuel Tanks: General

1. <u>PURPOSE</u>.

This AMC sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of CS-25 related to the strength of fuel tanks in emergency landing conditions.

2. <u>RELATED CERTIFICATION SPECIFICATIONS</u>.

CS 25.561 "Emergency Landing Conditions – General",

CS 25.721 "Landing Gear – General"

CS 25.994 "Fuel System Components"

CS 25J994 "Fuel System Components"

3. <u>BACKGROUND</u>.

For many years the JAA/EASA has required fuel tanks within the fuselage contour to be designed to withstand the inertial load factors prescribed for the emergency landing conditions as specified in JAR/CS 25.561. These load factors have been developed through many years of experience and are generally considered conservative design criteria applicable to objects of mass that could injure occupants if they came loose in a minor crash landing.

a. A minor crash landing is a complex dynamic condition with combined loading. However, in order to have simple and conservative design criteria, the emergency landing forces were established as conservative static ultimate load factors acting in each direction independently.

b. Recognising that the emergency landing load factors were applicable to objects of mass that could cause injury to occupants and that the rupture of fuel tanks in the fuselage could also be a serious hazard to the occupants, § 4b.420 of the Civil Air Regulations (CAR) part 4b (the predecessor of FAR 25) extended the emergency landing load conditions to fuel tanks that are located within the fuselage contour. Even though the emergency landing load factors were originally intended for solid items of mass, they were applied to the liquid fuel mass in order to develop hydrostatic pressure loads on the fuel tank structure. The application of the inertia forces as a static load criterion (using the full static head pressure) has been considered a conservative criterion for the typical fuel tank configuration within the fuselage contour. This conservatism has been warranted considering the hazard associated with fuel spillage.

c. CS 25.963 has required that fuel tanks, both in and near the fuselage, resist rupture under survivable crash conditions. The advisory material previously associated with CS 25.963 specifies design requirements for all fuel tanks that, if ruptured, could release fuel in or near the fuselage or near the engines in quantities sufficient to start a serious fire.

d. In complying with this CS requirement for wing tanks, several different techniques have been used by manufacturers to develop the fuel tank pressure loads due to the emergency landing inertia forces. The real emergency landing is actually a dynamic transient condition during which the fuel must flow in a very short period of time to re-establish a new level surface normal to the inertial force. For many tanks such as large swept wing tanks, the effect is that the actual pressure forces are likely to be much less than that which would be calculated from a static pressure based on a steady state condition using the full geometric pressure head. Because the use of the full pressure head results in unrealistically high pressures and creates a severe design penalty for wing tanks in swept wings, some manufacturers have used the local streamwise head rather than the full head. Other manufacturers have used the full pressure head but with less than a full tank of fuel. These methods of deriving the pressures for wing tanks have been accepted as producing design pressures for wing tanks that would more closely represent actual emergency landing conditions. The service record has shown no deficiency in strength for wing fuel tanks designed using these methods.

e. FAR 25 did not contain a requirement to apply fuel inertia pressure requirements to fuel tanks outside the fuselage contour, however, the FAA (like the JAA) has published Special Conditions to accomplish this for fuel tanks located in the tail surfaces. The need for Special Conditions was justified by the fact that these tanks are located in a rearward position from which fuel spillage could directly affect a large portion of the fuselage, possibly on both sides at the same time.

4. GENERAL.

CS 25.963(d) requires that fuel tanks must be designed, located, and installed so that no fuel is released in quantities sufficient to start a serious fire in otherwise survivable emergency landing conditions. The prescribed set of design conditions to be considered is as follows:

a. Fuel tank pressure loads. CS 25.963(d)(1) provides a conservative method for establishing the fuel tank ultimate emergency landing pressures. The phrase “fuel tanks outside the fuselage contour” is intended to include all fuel tanks where fuel spillage through any tank boundary would remain physically and environmentally isolated from occupied compartments by a barrier that is at least fire resistant as defined in CS-Definitions. In this regard, cargo compartments that share the same environment with occupied compartments would be treated the same as if they were occupied. The ultimate pressure criteria are different depending on whether the fuel tank under consideration is inside, or outside the fuselage contour. For the purposes of this paragraph a fuel tank should be considered inside the fuselage contour if it is inside the fuselage pressure shell. If part of the fuel tank pressure boundary also forms part of the fuselage pressure boundary then that part of the boundary should be considered as being within the fuselage contour. Figures 1 and 2 show examples of an underslung wing fuel tank and a fuel tank within a moveable tailplane, respectively, both of which would be considered as being entirely outside of the fuselage contour.

The equation for fuel tank pressure uses a factor L, based upon fuel tank geometry. Figure 3 shows examples of the way L is calculated for fuel pressures arising in the forward loading condition, while Figure 4 shows examples for fuel pressures arising in the outboard loading condition.

For Jet A(-1) fuel, a typical density of 785.0 kg/m^3 (6.55 lb/US gallon) may be assumed.

Any internal barriers to free flow of fuel may be considered as a solid pressure barrier provided:

(1) It can withstand the loads due to the expected fuel pressures arising in the conditions under consideration; and

(2) The time “T” for fuel to flow from the upstream side of the barrier to fill the cell downstream of the barrier is greater than 0.5 second. “T” may be conservatively estimated as:

$$\mathrm{T} = \frac{V}{\sum_{i=1}^{j} C_{di}\, a_i \sqrt{2g\, h_i\, K}}$$

where:

V = the volume of air in the fuel cell downstream of the barrier assuming a full tank at 1g flight conditions. For this purpose a fuel cell should be considered as the volume enclosed by solid barriers. In lieu of a more rational analysis, 2% of the downstream fuel volume should be assumed to be trapped air;

j = the total number of orifices in baffle rib;

Cd_i = the discharge coefficient for orifice i. The discharge coefficient may be conservatively assumed to be equal to 1.0 or it may be rationally based upon the orifice size and shape;

a_i = the area for orifice i;

g = the acceleration due to gravity;

h_i = the hydrostatic head of fuel upstream of orifice i, including all fuel volume enclosed by solid barriers;

K = the pressure design factor for the condition under consideration.

b. Near the fuselage/near the engines (Compliance with CS 25.963(d)(2).)

(1) For aircraft with wing mounted engines:

(i) The phrase “near the fuselage” is addressing those (parts of) wing fuel tanks located between the fuselage and the most inboard engine;

(ii) The phrase “near the engine” is addressing those (parts of) wing fuel tanks as defined in AMC 20-128A, figure 2, minimum distance of 10 inches (254 mm) laterally from potential ignition sources of the engine nacelle.

(2) For aircraft with fuselage mounted engines, the phrase “near the fuselage” is addressing those (parts of) wing fuel tanks located within one maximum fuselage width outside the fuselage boundaries.

c. Protection against crushing and scraping action (Compliance with CS 25.963(d)(4) and CS 25.721(b) and (c).).

Each fuel tank should be protected against the effects of crushing and scraping action (including thermal effects) of the fuel tank and surrounding airframe structure with the ground under the following minor crash landing conditions:

(i) An impact at 1.52 m/s (5 fps) vertical velocity on a paved runway at maximum landing weight, with all landing gears retracted and in any other possible combination of gear legs not extended. The unbalanced pitching and rolling moments due to the ground reactions are assumed to be reacted by inertia and by immediate pilot control action consistent with the aircraft under control until other structure strikes the ground. It should be shown that the loads generated by the primary and subsequent impacts are not of a sufficient level to rupture the tank. A reasonable attitude should be selected within the speed range from V_{L1} to 1.25 V_{L2} based upon the fuel tank arrangement.

V_{L1} equals to V_{S0} (TAS) at the appropriate landing weight and in standard sea-level conditions, and V_{L2} equals to V_{S0} (TAS) at the appropriate landing weight and altitudes in a hot day temperature of 22.8 degrees C (41 degrees F) above standard.

(ii) Sliding on the ground starting from a speed equal to V_{L1} up to complete stoppage, all gears retracted and with up to a 20° yaw angle and as a separate condition, sliding with any other possible combination of gear legs not extended and with a 0° yaw angle. The effects of runway profile need not be considered.

(iii) The impact and subsequent sliding phases may be treated as separate analyses or as one continuous analysis. Rational analyses that take into account the pitch response of the aircraft may be utilised, however care must be taken to assure that abrasion and heat transfer effects are not inappropriately reduced at critical ground contact locations.

(iv) For aircraft with wing mounted engines, if failure of engine mounts, or failure of the pylon or its attachments to the wing occurs during the impact or sliding phase, the subsequent effect on the integrity of the fuel tanks should be assessed. Trajectory analysis of the engine/pylon subsequent to the separation is not required.

(v) The above emergency landing conditions are specified at maximum landing weight, where the amount of fuel contained within the tanks may be sufficient to absorb the frictional energy (when the aircraft is sliding on the ground)without causing fuel ignition. When lower fuel states exist in the affected fuel tanks these conditions should also be considered in order to prevent fuel-vapour ignition.

d. Engine / Pylon separation. (Compliance with CS 25.721(c) and CS 25.963(d)(5).)

For configurations where the nacelle is likely to come into contact with the ground, failure under overload should be considered. Consideration should be given to the separation of an engine nacelle (or nacelle + pylon) under predominantly upward loads and under predominantly aft loads. The predominantly upward load and the predominantly aft load conditions should be analysed separately. It should be shown that at engine/pylon failure the fuel tank itself is not ruptured at or near the engine/pylon attachments.

e. Landing gear separation. (Compliance with CS 25.721(a) and CS 25.963(d)(5).)

Failure of the landing gear under overload should be considered, assuming the overloads to act in any reasonable combination of vertical and drag loads, in combination with side loads acting both inboard and outboard. In the absence of a more rational analysis, the side loads must be assumed to be up to 20% of the vertical load or 20% of the drag load, whichever is greater. It should be shown that at the time of separation the fuel tank itself is not ruptured at or near the landing gear attachments. The assessment of secondary impacts of the airframe with the ground following landing gear separation is not required. If the subsequent trajectory of a separated landing gear would likely puncture an adjacent fuel tank, design precautions should be taken to minimise the risk of fuel leakage.

f. Compliance with the provisions of this paragraph may be shown by analysis or tests, or both.

5. OTHER CONSIDERATIONS

a. Supporting structure. In accordance with CS 25.561(c) all large mass items that could break loose and cause direct injury to occupants must be restrained under all loads specified in CS 25.561(b). To meet this requirement, the supporting structure for fuel tanks, should be able to withstand each of the emergency landing load conditions, as far as they act in the 'cabin occupant sensitive directions', acting statically and independently at the tank centre of gravity as if it were a rigid body. Where an empennage includes a fuel tank, the empennage structure supporting the fuel tank should meet the restraint conditions applicable to large mass items in the forward direction.

Figure 1: Diagram of Fuel Tank in Underslung Wing that is Outside of the Fire Resistant Boundary

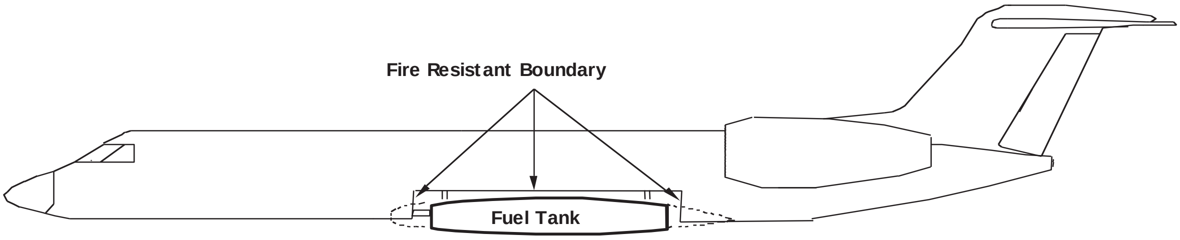


Figure 2: Diagram of Fuel Tank Within a Movable Tailplane

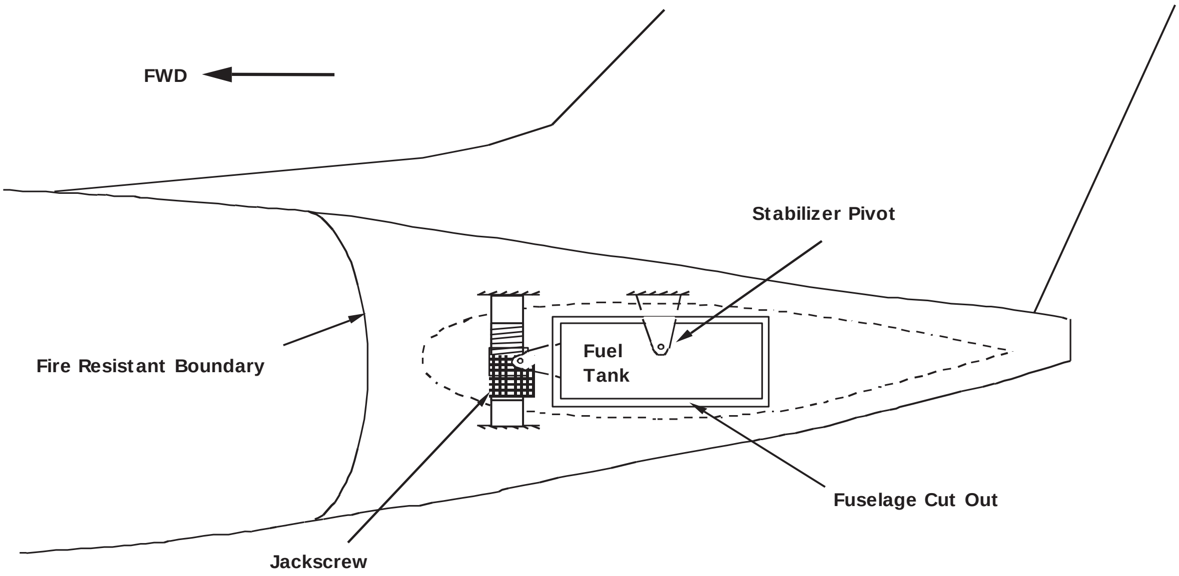
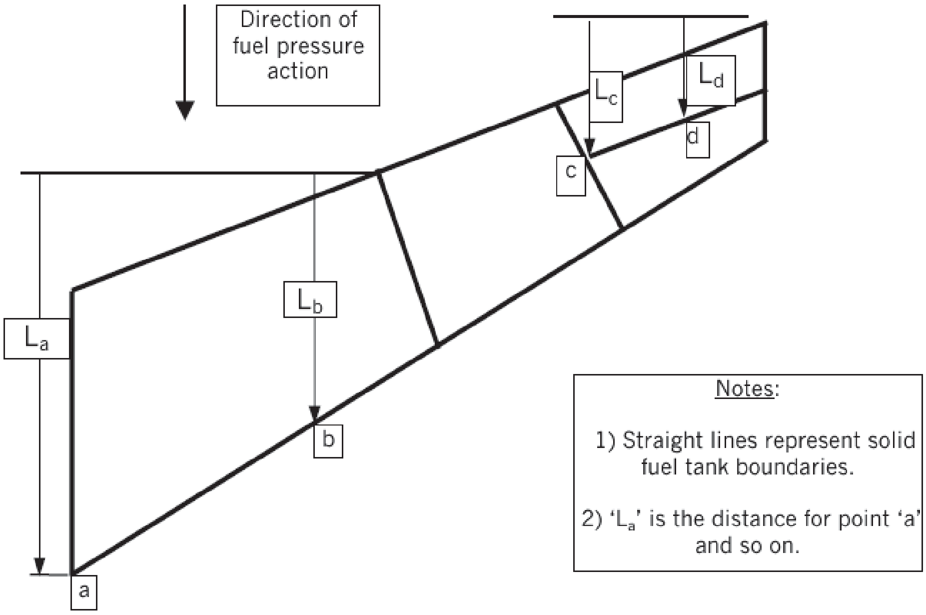


Figure 3- Example of Distances For Fuel Forward Acting Design Pressure Calculations

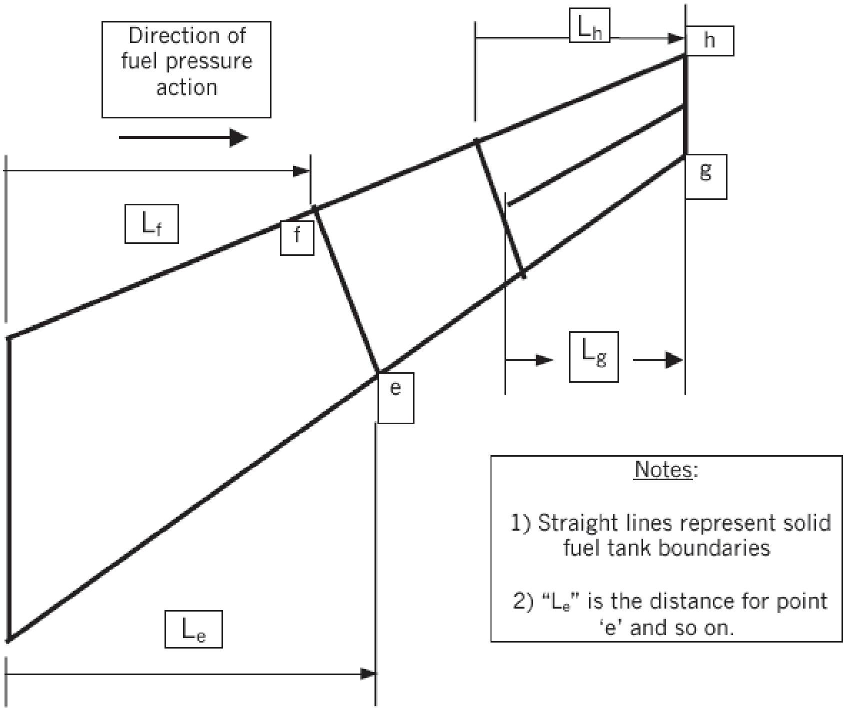


Notes:

1) Straight lines represent solid fuel tank boundaries.

2) 'L_a' is the distance for point 'a' and so on.

Figure 4 - Example of Distances For Fuel Outboard Acting Design Pressure Calculations



Notes:

1) Straight lines represent solid fuel tank boundaries

2) "L_e" is the distance for point 'e' and so on.

[Amdt No: 25/3]