d. Deactivated Reverser: Any thrust reverser that has been deliberately inhibited such that it is precluded from performing a normal deploy/stow cycle, even if commanded to do so.

e. Exceptional Piloting Skill and/or Strength: Refer to CS 25.143(c)(c) («Controllability and Manoeuvrability—General»).

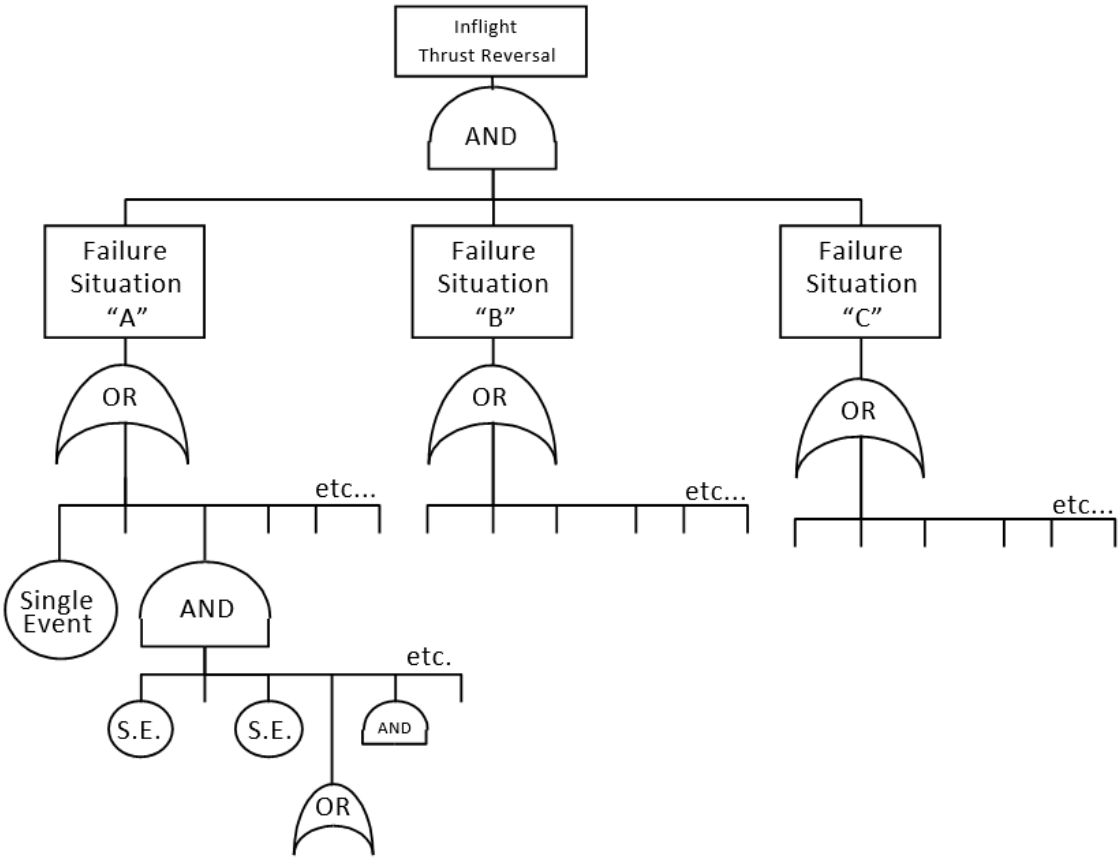
f. Extremely Improbable: see AMC 25.1309

g. Extremely Remote: see AMC 25.1309

h. Failure: see AMC 25.1309

i. Failure Situation: All failures that result in the malfunction of one independent command and/or restraint feature that directly contributes to the top level Fault Tree Analysis event (i.e., unwanted in-flight thrust reversal). For the purpose of illustration, Figure 1, below, provides a fault tree example for a scenario of three «failure situations» leading to unwanted in-flight thrust reversal.

Figure 1: TOP EVENT



Reverser System with three independent command/restraint features shown for reference only.

j. Hazardous: see AMC 25.1309

k. In-flight: that part of aeroplane operation beginning when the wheels are no longer in contact with the ground during the take-off and ending when the wheels again contact the ground during landing.

l. Light Crosswind: For purposes of this AMC, a light crosswind is a 19 km/h (10 Kt). wind at right angles to the direction of take-off or landing which is assumed to occur on every flight.

m. Light Turbulence: Turbulence that momentarily causes slight, erratic changes in altitude and/or attitude (pitch, roll, and/or yaw), which is assumed to occur on every flight.

n. Major: see AMC 25.1309

o. Maximum exposure time: The longest anticipated period between the occurrence and elimination of the failure.

p. Normal Flight Envelope: An established boundary of parameters (velocity, altitude, angle of attack, attitude) associated with the practical and routine operation of a specific aeroplane that is likely to be encountered on a typical flight and in combination with prescribed conditions of light turbulence and light crosswind.

q. Pre-existing failure: Failure that can be present for more than one flight.

r. Thrust Reversal: A movement of all or part of the thrust reverser from the forward thrust position to a position that spoils or redirects the engine airflow.

s. Thrust Reverser System: Those components that spoil or redirect the engine thrust to decelerate the aeroplane. The components include:

— the engine-mounted hardware,

— the reverser control system,

— indication and actuation systems, and

— any other aeroplane systems that have an effect on the thrust reverser operation.

t. Turbojet thrust reversing system: Any device that redirects the airflow momentum from a turbojet engine so as to create reverse thrust. Systems may include:

— cascade-type reversers,

— target or clamshell-type reversers,

— pivoted-door petal-type reversers,

— deflectors articulated off either the engine cowling or aeroplane structure,

— targetable thrust nozzles, or

— a propulsive fan stage with reversing pitch.

u. Turbojet (or turbofan): A gas turbine engine in which propulsive thrust is developed by the reaction of gases being directed through a nozzle.

6. DEMONSTRATING COMPLIANCE WITH CS 25.933(a).

The following Sections 7 through 10 of this AMC provide guidance on specific aspects of compliance with CS 25.933(a), according to four different means or methods:

— Controllability (Section 7),

— Reliability (Section 8),

— Mixed controllability / reliability (Section 9),

— Deactivated reverser (Section 10).

7. «CONTROLLABILITY OPTION»: PROVIDE CONTINUED SAFE FLIGHT AND LANDING FOLLOWING ANY IN-FLIGHT THRUST REVERSAL.

The following paragraphs provide guidance regarding an acceptable means of demonstrating compliance with CS 25.933(a)(1).

7.a. General. For compliance to be established with CS 25.933(a) by demonstrating that the aeroplane is capable of continued safe flight and landing following any in-flight thrust reversal (the «controllability option» provided for under CS 25.933(a)(1)), the aspects of structural integrity, performance, and handling qualities must be taken into account. The level of accountability should be appropriate to the probability of in-flight thrust reversal, in accordance with the following sections.

To identify the corresponding failure conditions and determine the probability of their occurrence, a safety analysis should be carried out, using the methodology described in CS 25.1309. The reliability of design features, such as auto-idle and automatic control configurations critical to meeting the following controllability criteria, also should be considered in the safety analysis.

Appropriate alerts and/or other indications should be provided to the crew, as required by CS 25.1309(c) (Ref. AMC 25.1309).

The inhibition of alerts relating to the thrust reverser system during critical phases of flight should be evaluated in relation to the total effect on flight safety (Ref. AMC 25.1309).

Thrust reversal of a cyclic or erratic nature (e.g., repeated deploy/stow movement of the thrust reverser) should be considered in the safety analysis and in the design of the alerting/indication systems.

Input from the flight crew and human factors specialists should be considered in the design of the alerting and/or indication provisions.

The controllability compliance analysis should include the relevant thrust reversal scenario that could be induced by a rotorburst event.

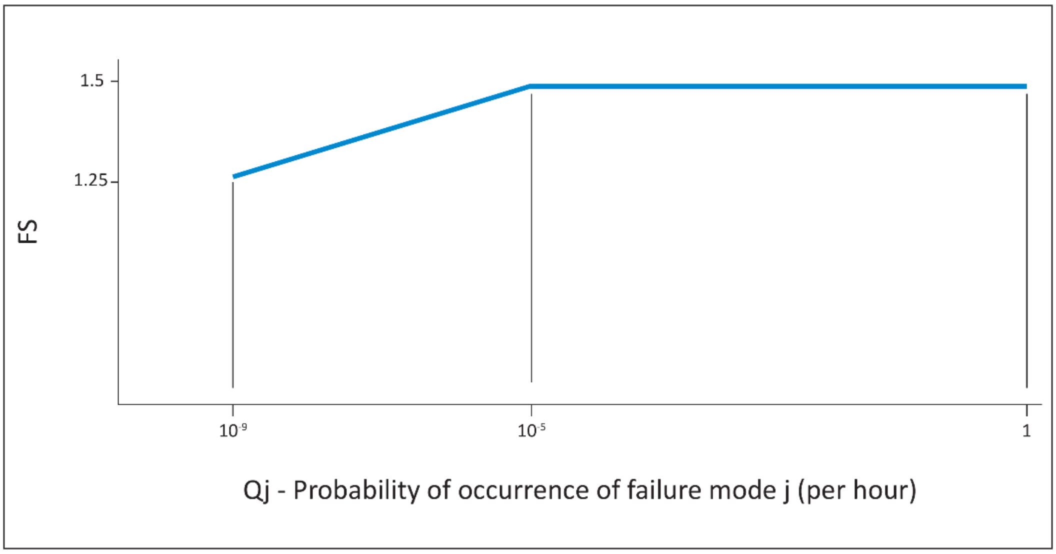
When demonstrating compliance using this «controllability option» approach, if the aeroplane might experience an in-flight thrust reversal outside the «controllable flight envelope» anytime during the entire operational life of all aeroplanes of this type, then further compliance considerations as described in Section 9 («MIXED CONTROLLABILITY / RELIABILITY OPTION») of this AMC, below, should be taken into account.

7.b. Structural Integrity. For the «controllability option,» the aeroplane must be capable of successfully completing a flight during which an unwanted in-flight thrust reversal occurs. An assessment of the integrity of the aeroplane structure is necessary, including an assessment of the structure of the deployed thrust reverser and its attachments to the aeroplane.

In conducting this assessment, the normal structural loads, as well as those induced by failures and forced vibration (including buffeting), both at the time of the event and for continuation of the flight, must be shown to be within the structural capability of the aeroplane.

At the time of occurrence, starting from 1-g level flight conditions, at speeds up to V_C, a realistic scenario, including pilot corrective actions, should be established to determine the loads occurring at the time of the event and during the recovery manoeuvre. The aeroplane should be able to withstand these loads multiplied by an appropriate factor of safety that is related to the probability of unwanted in-flight thrust reversal. The factor of safety is defined in Figure 2, below. Conditions with high lift devices deployed also should be considered at speeds up to the appropriate flap limitation speed.

Figure 2: Factor of safety at the time of occurrence



For continuation of the flight following in-flight thrust reversal, considering any appropriate reconfiguration and flight limitations, the following apply:

7.b.(1) Static strength should be determined for loads derived from the following conditions at speeds up to V_C, or the speed limitation prescribed for the remainder of the flight:

(i) 70% of the limit flight manoeuvre loads; and separately

(ii) the discrete gust conditions specified in CS 25.341(a) (but using 40% of the gust velocities specified for V_C).

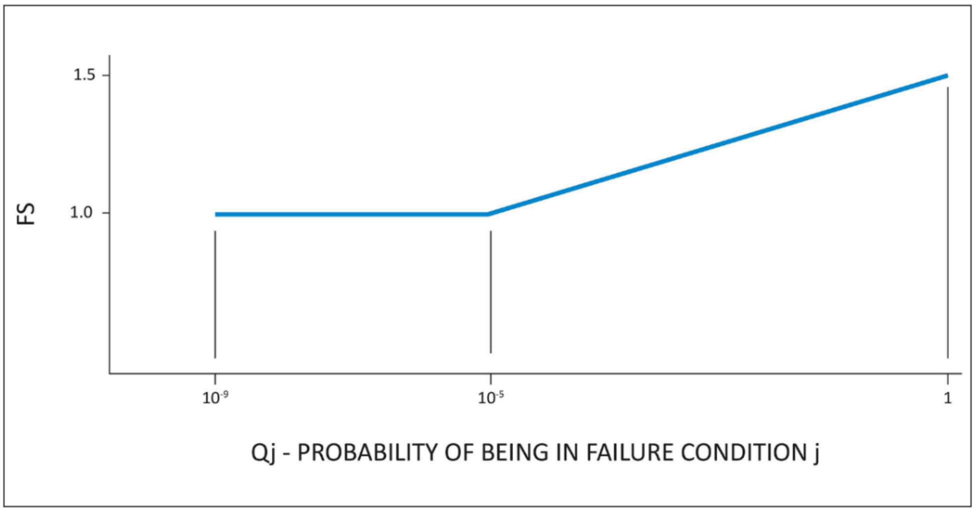
7.b.(2) For the aeroplane with high lift devices deployed, static strength should be determined for loads derived from the following conditions at speeds up the appropriate flap design speed, or any lower flap speed limitation prescribed for the remainder of the flight:

(i) A balanced manoeuvre at a positive limit load factor of 1.4; and separately

(ii) the discrete gust conditions specified in CS 25.345(a)(2) (but using 40% of the gust velocities specified).

7.b.(3) For static strength substantiation, each part of the structure must be able to withstand the loads specified in sub-paragraph 7.b.(1) and 7.b.(2) of this paragraph, multiplied by a factor of safety depending on the probability of being in this failure state. The factor of safety is defined in Figure 3, below.

Figure 3: Factor of safety for continuation of flight



Qj = is the probability of being in the configuration with the unwanted in-flight thrust reversal

Qj = (Tj)(Pj) where:

Tj = average time spent with unwanted in-flight thrust reversal (in hours)

Pj = probability of occurrence of unwanted in-flight thrust reversal (per hour)

If the thrust reverser system is capable of being restowed following a thrust reversal, only those loads associated with the interval of thrust reversal need to be considered. Historically, thrust reversers have often been damaged as a result of unwanted thrust reversal during flight. Consequently, any claim that the thrust reverser is capable of being restowed must be adequately substantiated, taking into account this adverse service history.

7.c. Performance

7.c.(1) General Considerations: Most failure conditions that have an effect on performance are adequately accounted for by the requirements addressing a «regular» engine failure (i.e., involving only loss of thrust and not experiencing any reverser anomaly). This is unlikely to be the case for failures involving an unwanted in-flight thrust reversal, which can be expected to have a more adverse impact on thrust and drag than a regular engine failure. Such unwanted in-flight thrust reversals, therefore, should be accounted for specifically, to a level commensurate with their probability of occurrence.

The performance accountability that should be provided is defined in Sections 7.c.(2) and 7.c.(3) as a function of the probability of the unwanted in-flight thrust reversal. Obviously, for unwanted in-flight thrust reversals less probable than 1×10^{-9} /fh, certification may be based on reliability alone, as described in Section 8 («RELIABILITY OPTION») of this AMC. Furthermore, for any failure conditions where unwanted in-flight thrust reversal would impact safety, the aeroplane must meet the safety/reliability criteria delineated in CS 25.1309.

7.c.(2) Probability of unwanted in-flight thrust reversal greater than $1x10^{-7}$/fh: Full performance accountability must be provided for the more critical of a regular engine failure and an unwanted in-flight thrust reversal.

To determine if the unwanted in-flight thrust reversal is more critical than a regular engine failure, the normal application of the performance requirements described in CS-25, Subpart B, as well as the applicable operating requirements, should be compared to the application of the following criteria, which replace the accountability for a critical engine failure with that of a critical unwanted in-flight thrust reversal:

— CS 25.111, «Take-off path»: The takeoff path should be determined with the critical unwanted thrust reversal occurring at V_{LOF} instead of the critical engine failure at V_{EF}. No change to the state of the engine with the thrust reversal that requires action by the pilot may be made until the aircraft is 122 m (400 ft) above the takeoff surface.

— CS 25.121, «Climb: one-engine-inoperative»: Compliance with the one-engine-inoperative climb gradients should be shown with the critical unwanted in-flight thrust reversal rather than the critical engine inoperative.

— CS 25.123, «En-route flight paths»: The en-route flight paths should be determined following occurrence of the critical unwanted in-flight thrust reversal(s) instead of the critical engine failure(s), and allowing for the execution of appropriate crew procedures. For compliance with the applicable operating rules, an unwanted in-flight thrust reversal(s) at the most critical point en-route should be substituted for the engine failure at the most critical point en-route.

Performance data determined in accordance with these provisions, where critical, should be furnished in the Aeroplane Flight Manual as operating limitations.

Operational data and advisory data related to fuel consumption and range should be provided for the critical unwanted in-flight thrust reversal to assist the crew in decision making. These data may be supplied as simple factors or additives to apply to normal all-engines-operating fuel consumption and range data. For approvals to conduct extended range operations with two-engine aeroplanes (ETOPS), the critical unwanted in-flight thrust reversal should be considered in the critical fuel scenario (paragraph 10d(4)(iii) of Information Leaflet no. 20: ETOPS).

In addition to requiring full performance accountability as it relates to the specific aeroplane performance requirements of Subpart B, all other aspects of the aeroplane's performance following a non-restowable in-flight thrust reversal (e.g. capability to climb and maintain 305m (1000 feet) AGL) must be found adequate to comply with the intent of CS 25.933(a)(1)(ii).

7.c.(3) Probability of unwanted in-flight thrust reversal equal to or less than $1x10^{-7}$/fh, but greater than $1x10^{-9}$/fh: With the exception of the takeoff phase of flight, which needs not account for unwanted in-flight thrust reversal, the same criteria should be applied as in Section 7.c.(2), above, for the purposes of providing advisory data and procedures to the flight crew. Such performance data, however, need not be applied as operating limitations. The takeoff data addressed by Section 7.c.(2), above (takeoff speeds, if limited by V_{MC}, takeoff path, and takeoff climb gradients), does not need to be provided, as it would be of only limited usefulness if not applied as a dispatch limitation.

However, the takeoff data should be determined and applied as operating limitations if the unwanted in-flight thrust reversal during the take-off phase is the result of a single failure.

As part of this assessment, the effect of an unwanted in-flight thrust reversal on approach climb performance, and the ability to execute a go-around manoeuvre should be determined and used to specify crew procedures for an approach and landing following a thrust reversal. For example, the procedures may specify the use of a flap setting less than that specified for landing, or an airspeed greater than the stabilised final approach airspeed, until the flight crew is satisfied that a landing is assured and a go-around capability need no longer be maintained. Allowance may be assumed for execution of appropriate crew procedures subsequent to the unwanted thrust reversal having occurred. Where a number of thrust reversal states may occur, these procedures for approach and landing may, at the option of the applicant, be determined either for the critical thrust reversal state or for each thrust reversal state that is clearly distinguishable by the flight crew.

Operational data and advice related to fuel consumption and range should be provided for the critical unwanted in-flight thrust reversal to assist the crew in decision-making. These data may be supplied as simple factors or additives to apply to normal all-engines-operating fuel consumption and range data.

The aeroplane performance capabilities following a non-restowable in-flight thrust reversal must be such that the probability of preventing continued safe flight (e.g. capability to climb and maintain 305m (1000 feet) AGL) and landing at an airport (i.e. either destination or diversion) is extremely improbable.

7.d. Handling Qualities

7.d.(1) Probability of unwanted in-flight thrust reversal greater than $1x10^{-7}$/fh: The more critical of an engine failure (or flight with engine(s) inoperative), and an unwanted in-flight thrust reversal, should be used to show compliance with the controllability and trim requirements of CS-25, Subpart B. In addition, the criteria defined in Section 7.d.(2), below, also should be applied. To determine if the unwanted in-flight thrust reversal is more critical than an engine failure, the normal application of the CS-25, Subpart B, controllability and trim requirements should be compared to the application of the following criteria, which replace the accountability for a critical engine failure with that of a critical unwanted in-flight thrust reversal:

— CS 25.143, «Controllability and Manoeuvrability - General»: the effect of a sudden unwanted in-flight thrust reversal of the critical engine, rather than the sudden failure of the critical engine, should be evaluated in accordance with CS 25.143(b)(1) and the associated guidance material.

  Control forces associated with the failure should comply with CS 25.143(c).

— CS 25.147, «Directional and lateral control»: the requirements of CS 25.147(a), (b), (c), and (d) should be complied with following critical unwanted in-flight thrust reversal(s) rather than with one or more engines inoperative.

— CS 25.149, «Minimum control speed»: the values of V_{MC} and V_{MCL} should be determined with a sudden unwanted in-flight thrust reversal of the critical engine rather than a sudden failure of the critical engine.

— CS 25.161, «Trim» the trim requirements of CS 25.161(d) and (e)should be complied with following critical unwanted in-flight thrust reversal(s), rather than with one or more engines inoperative.

Compliance with these requirements should be demonstrated by flight test. Simulation or analysis will not normally be an acceptable means of compliance for such probable failures.

7.d.(2) Probability of unwanted thrust reversal equal to or less than $1x10^{-7}$/fh, but greater than $1x10^{-9}$/fh: failure conditions with a probability equal to or less than $1x10^{-7}$/fh are not normally evaluated against the specific controllability and trim requirements of CS-25, Subpart B. Instead, the effects of unwanted in-flight thrust reversal should be evaluated on the basis of maintaining the capability for continued safe flight and landing, taking into account pilot recognition and reaction time. One exception is that the minimum control speed requirement of CS 25.149 should be evaluated to the extent necessary to support the performance criteria specified in Section 7.c.(3), above, related to approach, landing, and go-around.

Recognition of the failure may be through the behaviour of the aircraft or an appropriate failure alerting system, and the recognition time should not be less than one second. Following recognition, additional pilot reaction times should be taken into account, prior to any corrective pilot actions, as follows:

— Landing: no additional delay

— Approach: 1 second

— Climb, cruise, and descent: 3 seconds; except when in auto-pilot engaged manoeuvring flight, or in manual flight, when 1 second should apply.

Both auto-pilot engaged and manual flight should be considered.

The unwanted in-flight thrust reversal should not result in any of the following:

— exceedance of an airspeed halfway between V_{MO} and V_{DF}, or Mach Number halfway between M_{MO} and M_{DF}

— a stall

— a normal acceleration less than a value of 0g

— bank angles of more than 60° en-route, or more than 30° below a height of 305m (1000 ft)

— degradation of flying qualities assessed as greater than Major for unwanted in-flight thrust reversal more probable than $1x10^{-7}$/fh; or assessed as greater than Hazardous for failures with a probability equal to or less than $1x10^{-7}$/fh, but greater $1x10^{-9}$/fh

— the roll control forces specified in CS 25.143(c), except that the long term roll control force should not exceed 10 lb

— structural loads in excess of those specified in Section 7.b., above.

Demonstrations of compliance may be by flight test, by simulation, or by analysis suitably validated by flight test or other data.

7.d.(3) Probability of in-flight thrust reversal less than $1x10^{-9}$/fh: Certification can be based on reliability alone as described in Section 8, below.

8. <u>'RELIABILITY OPTION': PROVIDE CONTINUED SAFE FLIGHT AND LANDING BY PREVENTING ANY IN-FLIGHT THRUST REVERSAL</u>

The following paragraphs provide guidance regarding an acceptable means of demonstrating compliance with CS 25.933(a)(1)(ii).

8.a. General. For compliance to be established with CS 25.933(a) by demonstrating that unwanted in-flight thrust reversal is not anticipated to occur (the «reliability option» provided for under CS 25.933(a)(1)(ii)), the aspects of system reliability, maintainability, and fault tolerance; structural integrity; and protection against zonal threats such as uncontained engine rotor failure or fire must be taken into account.

8.b. System Safety Assessment (SSA): Any demonstration of compliance should include an assessment of the thrust reverser control, indication and actuation system(s), including all interfacing power-plant and aeroplane systems (such as electrical supply, hydraulic supply, flight/ground status signals, thrust lever position signals, etc.) and maintenance.

The reliability assessment should include:

— the possible modes of normal operation and of failure;

— the resulting effect on the aeroplane considering the phase of flight and operating conditions;

— the crew awareness of the failure conditions and the corrective action required;

— failure detection capabilities and maintenance procedures, etc.; and

— the likelihood of the failure condition.

Consideration should be given to failure conditions being accompanied or caused by external events or errors.

The SSA should be used to identify critical failure paths for the purpose of conducting in-depth validation of their supporting failure mode, failure rates, exposure time, reliance on redundant subsystems, and assumptions, if any. In addition, the SSA can be used to determine acceptable time intervals for any required maintenance intervals (ref. AMC 25.1309 and AMC 25.19).

The primary intent of this approach to compliance is to improve safety by promoting more reliable designs and better maintenance, including minimising pre-existing faults. Latent failures involved in unwanted in-flight thrust reversal should be avoided whenever practical. The design configurations in paragraphs 8.b.(2) and 8.b.(3) have traditionally been considered to be practical and considered to be acceptable to EASA.

8.b.(1) The thrust reverser system should be designed so that any in-flight thrust reversal that is not shown to be controllable in accordance with Section 7,above, is extremely improbable (i.e., average probability per hour of flight of the order of $1x10^{-9}$/fh. or less) and does not result from a single failure or malfunction. And

8.b.(2) For configurations in which combinations of two-failure situations (ref. Section 5, above) result in in-flight thrust reversal, the following apply:

Neither failure may be pre-existing (i.e., neither failure situation can be undetected or exist for more than one flight); the means of failure detection must be appropriate in consideration of the monitoring device reliability, inspection intervals, and procedures.

The occurrence of either failure should result in appropriate cockpit indication or be self-evident to the crew to enable the crew to take necessary actions such as discontinuing a take-off, going to a controllable flight envelope en-route, diverting to a suitable airport, or reconfiguring the system in order to recover single failure tolerance, etc. And

8.b.(3) For configurations in which combinations of three or more failure situations result in in-flight thrust reversal, the following applies:

In order to limit the exposure to pre-existing failure situations, the maximum time each pre-existing failure situation is expected to be present should be related to the frequency with which the failure situation is anticipated to occur, such that their product is 1×10^{-3} or less.

The time each failure situation is expected to be present should take into account the expected delays in detection, isolation, and repair of the causal failures.

8.c. Structural Aspects: For the «reliability option,» those structural load paths that affect thrust reversal should be shown to comply with the static strength, fatigue, damage tolerance, and deformation requirements of CS-25. This will ensure that unwanted in-flight thrust reversal is not anticipated to occur due to failure of a structural load path, or due to loss of retention under ultimate load throughout the operational life of the aeroplane.

8.d. Uncontained Rotor Failure: In case of rotor failure, compliance with CS 25.903(d)(1) should be shown, using advisory materials (AC, user manual, etc.) supplemented by the methods described below. The effects of associated loads and vibration on the reverser system should be considered in all of the following methods of minimising hazards:

8.d.(1) Show that engine spool-down characteristics or potential reverser damage are such that compliance with Section 7, above, can be shown.

8.d.(2) Show that forces that keep the thrust reverser in stable stowed position during and after the rotor burst event are adequate.

8.d.(3) Locate the thrust reverser outside the rotor burst zone.

8.d.(4) Protection of thrust reverser restraint devices: The following guidance material describes methods of minimising the hazard to thrust reverser stow position restraint devices located within rotorburst zones. The following guidance material has been developed on the basis of all of the data available to date and engineering judgement.

8.d.(4)(i) Fragment Hazard Model:

(A) Large Fragments

— Ring Disks (see Figure 4.a.) - Compressor drum rotors or spools with ring disks have typically failed in a rim peeling mode when failure origins are in the rim area. This type of failure typically produces uncontained fragment energies, which are mitigated by a single layer of conventional aluminium honeycomb structure. (Note: This guidance material is based upon field experience and, as such, its application should be limited to aluminium sheet and honeycomb fan reverser construction. Typical construction consists of 12.7 mm (a half inch) thickness of .003-.004” aluminium foil honeycomb with .030" thick