damage tolerance rules and advisory materials, unless otherwise stated in this AMC or addressed by other means.

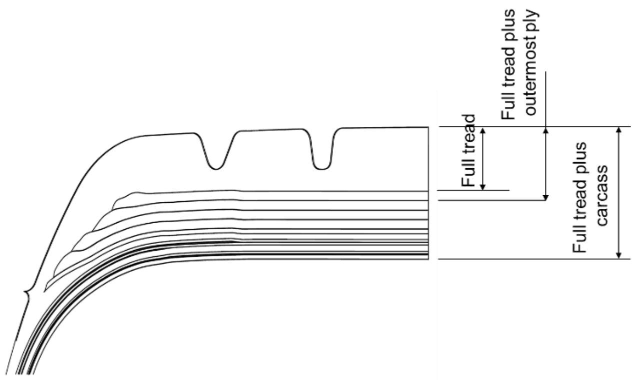
3.3. Fuel tank penetration

In-service experience shows a good safety record for the fuel tanks located within the torsion box of high aspect ratio wings manufactured of light metal alloy, owing to the intrinsic characteristics of the structure, including the wing skin gauge and typical arrangement of the stringers and ribs. Therefore, for tanks located within similar structures, in the absence of any unusual design feature(s), fuel tank penetration evaluation needs only to consider small tyre debris.

3.4. Definitions

Carcass of a tyre: This comprises the entire main body of a tyre (also named the casing) including the materials under the tread, the sidewall, and steel belts if any.

Full tread: The thickness of the tread rubber measured from the outer tread surface to the top of the outermost fabric or steel layer, including the rubber thickness above and below the tread groove bottom. Refer to the figure below (section of a tyre):



Hazardous fuel leak: a definition is provided in AMC 25.963(e).

Maximum unloaded operational pressure: Unloaded rated tyre pressure (available from the TRA Year Book) divided by the 1.07 factor from CS 25.733(c)(1).

Minimum tyre speed rating: The lowest tyre speed rating certified for the aeroplane in compliance with CS 25.733(a) or (c). The aeroplane manufacturer may decide to certify several tyre speed ratings; in this case, the lowest certified speed rating value should be taken as the 'minimum tyre speed rating' used in the models of this AMC.

Total tread area: $\prod . D_G . W_{SG}$

Terms used in accordance with the Tire and Rim Association (TRA) Aircraft Year Book[1]:

— D = TRA Rim Diameter

— D_G = TRA Grown Tyre Diameter

— W_{SG} = TRA Maximum Grown Shoulder Width

[1] The Tire and Rim Association, Inc. (TRA) is the standardizing body for the tire, rim, valve and allied parts industry for the United States. TRA was founded in 1903 and its primary purpose is to establish and promulgate interchangeability standards for tires, rims, valves and allied parts. TRA standards are published in the Tire and Rim Year Book, Aircraft Year Book and supplemental publications. More information available at: http://www.us-tra.org/index.html.

Tyre speed rating: The maximum ground speed at which the tyre has been tested in accordance with (E)TSO C62e.

4. Threat models

Model 1 — Tyre Debris Threat Model

Applicability: landing gear extended

(1) Threats occurring when the tyre is in contact with the ground release tyre debris.

Two tyre debris sizes are considered.

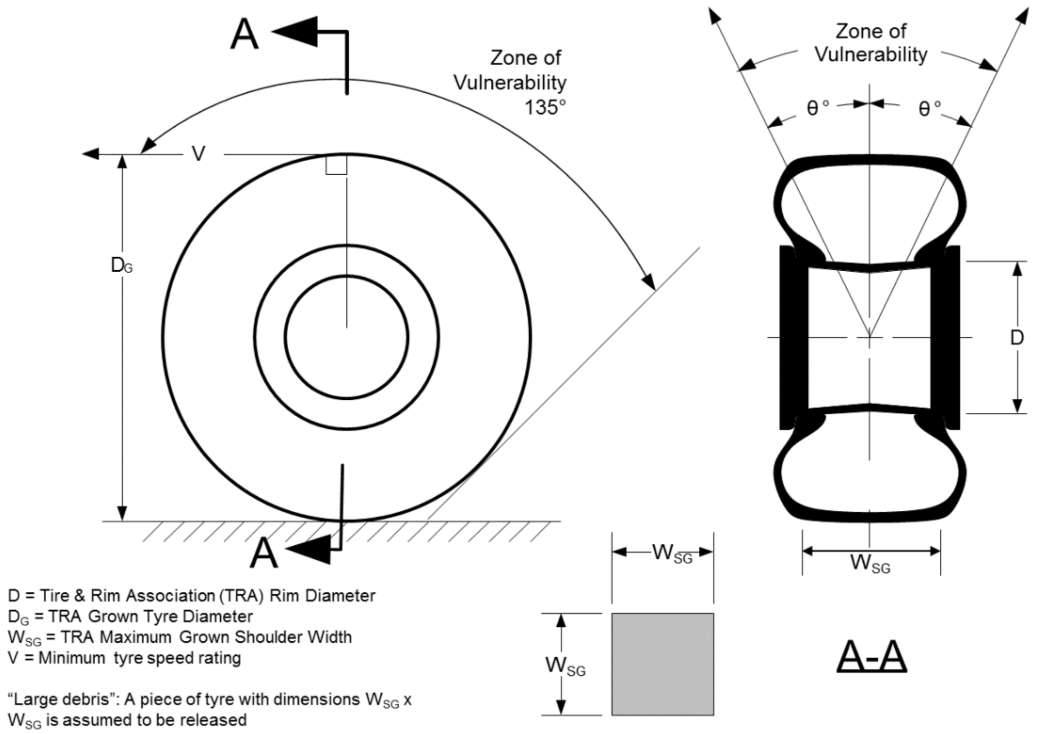
These debris are assumed to be released from the tread area of the tyre and projected towards the aircraft within the zones of vulnerability identified in Figure 1:

(i) a 'large debris' with dimensions WSG × WSG at DG and a thickness of the full tread plus outermost ply (i.e. the reinforcement or protector ply). The angle of vulnerability θ is 15°.

(ii) a 'small debris' consisting of 1 per cent of the total tyre mass, with an impact load distributed over an area equal to 1.5 per cent of the total tread area. The angle of vulnerability θ is 30°.

The debris have a speed equivalent to the minimum tyre speed rating certified for the aircraft (the additional velocity component due to the release of carcass pressure need not be taken into account).

Figure 1 – Tyre Debris Threats



(2) Protection of the fuel tank structure and pass-fail criteria on effects of penetration

(2.1) The large tyre debris size as defined in (i) above is assumed to penetrate and open the fuel tank or fuel system structure located in the zone of vulnerability defined in (i). It is used to define the opening size of the structural damage. A fuel leakage is assumed to occur whenever either the fuel tank structure or any structural element of fuel system components is struck by this large debris. It need not be used as a sizing case for structural design.

The fuel leakage should not result in hazardous quantities of fuel entering areas of the aeroplane that could present a hazard such as, but not limited to:

1. an engine air intake,
2. an APU air intake, or
3. a cabin air intake.

All practical measures should be taken to avoid fuel coming into contact with an ignition source (which may also result from the tyre failure event, e.g. electrical wire damage).

This should be shown by test or analysis, or a combination of both, for each engine forward thrust condition and each approved reverse thrust condition.

Alternatively, it is acceptable to demonstrate that the large tyre debris as defined in (i) above will not cause damage sufficient to allow a hazardous fuel leak whenever fuel tank deformation or rupture has been induced (including through propagation of pressure waves or cracking sufficient to allow a hazardous fuel leak).

(2.2) The small tyre debris as defined in (ii) should not create damage sufficient to allow a hazardous fuel leak in the zone of vulnerability defined in (ii).

(3) Protection of systems and pass-fail criteria

The two tyre debris sizes (defined in (i) and (ii) above) are considered. The sizes of debris are to be considered for the separation of systems.

When shielding is required (to protect a component or system), or when an energy analysis is required (for instance, for the validation of the structural parts of systems), the small debris defined in (ii) should be used.

An initial tyre failure can also result in failure of, and debris from, the companion tyre. This can occur even when the tyres have been designed to have double dynamic overload capability.

The analysis for the segregation of systems installation and routing should take this companion tyre failure into account inside the vulnerability zone defined by $\theta = 15°$ (either side of the tyre centre line) and only considering both tyres releasing large debris. Inside zones defined by $15° < \theta \leq 30°$, where only the small debris size is applicable, only debris (defined in (ii)) from a single tyre needs to be considered.

A 'companion' tyre is a tyre on the same axle.

To demonstrate compliance with the applicable Certification Specifications, the following approach should be used:

(a) Identify all hazards associated with the possible impact areas defined by Figure 1, including simultaneous/cascade failure of companion tyres.

(b) All practicable design precautions should be taken to eliminate all Catastrophic failure situations by means of system separation and/or impact resistant shielding and/or redesign. Impact resistance should be assessed for small debris (type (ii)) impacts only. Consideration should also be given to Hazardous failure situations when showing compliance in accordance with CS 25.1309.

(c) Any Catastrophic failure situation that remains after accomplishment of step (b) above will be submitted to the Agency for consideration in accordance with step (d) below.

(d) If the Agency concludes that the applicant has taken all practicable precautions to prevent a Catastrophic failure situation and the probability of the occurrence is consistent with the hazard classification (assuming a probability of companion tyre failure, if applicable, equal to 10 per cent), the design would be considered as compliant with the intent of CS 25.734.

Model 2 — Wheel Flange Debris Threat Model

Applicability: gear extended

(1) It is considered that a 60° arc segment of the wheel flange can be released laterally, in the zones identified in Figure 2. The speed of release is 100 m/s (328 ft/s).

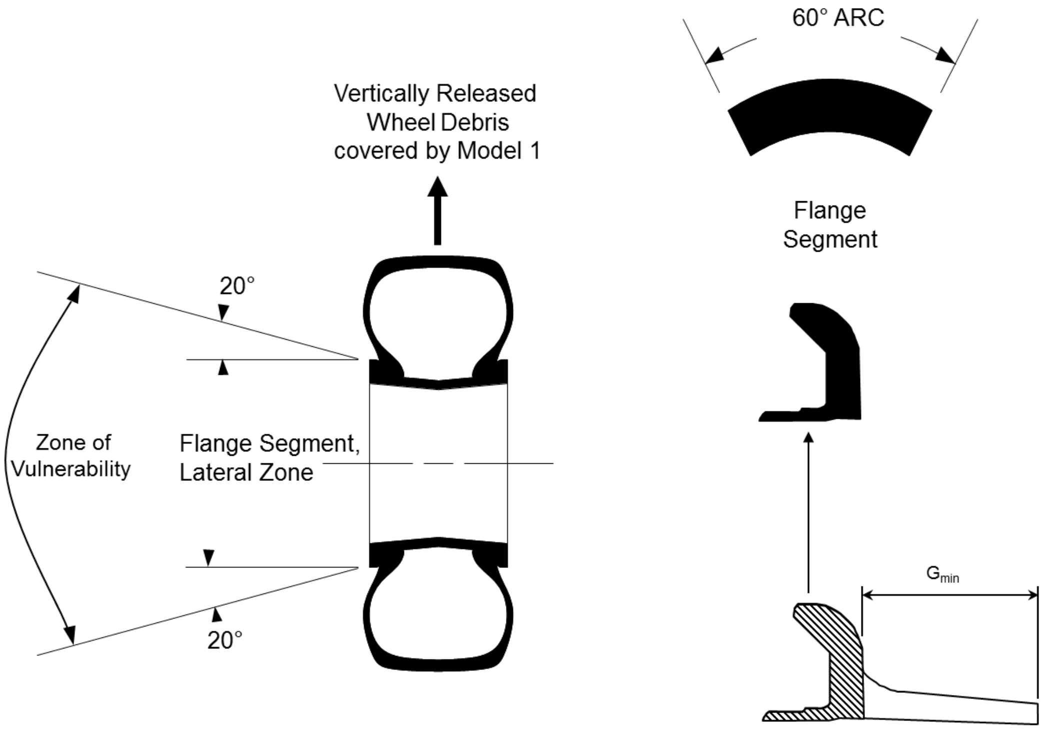
Where multiple wheels are installed on a landing gear leg, the lateral release of only the flange on the outer wheel halves needs to be considered.

If only a single wheel is installed on a landing gear leg, then the lateral release of either flange shall be considered.

(2) Vertically released debris are covered by Model 1 tyre debris.

(3) The debris should be considered to impact in the most critical condition.

Figure 2 – Wheel Flange Release Threat



Model 3 — Flailing Tyre Strip Threat Model

(1) Model 3E: Landing Gear Extended

A flailing tyre strip with a length of 2.5 WSG and a width of WSG/2 will remain attached to the outside diameter of the rotating tyre at take-off speeds.

The thickness (t) of the loose strip of tyre is the full tread plus the carcass of the tyre. If the applicant demonstrates that the carcass will not fail, then the thickness may be reduced to full tread plus outermost ply (i.e. the reinforcement or protector ply).

The strip has a speed equivalent to the minimum tyre speed rating certified for the aircraft. For this threat the zone of vulnerability is 30°, as shown in Figure 3.

(2) Model 3R: Landing Gear Retracting or Retracted

The loose tyre strip and the conditions remain unchanged from that considered for the Gear Extended case. However, due to the wheel spin down after take-off, the rotational speed of the wheel may be lower or even zero as it enters the wheel bay.

If the aeroplane is equipped with a system braking the wheel during landing gear retraction ('retraction brake'), then the applicant may take credit for this system provided:

(i) the retraction braking system is reliable and its failure is not latent;

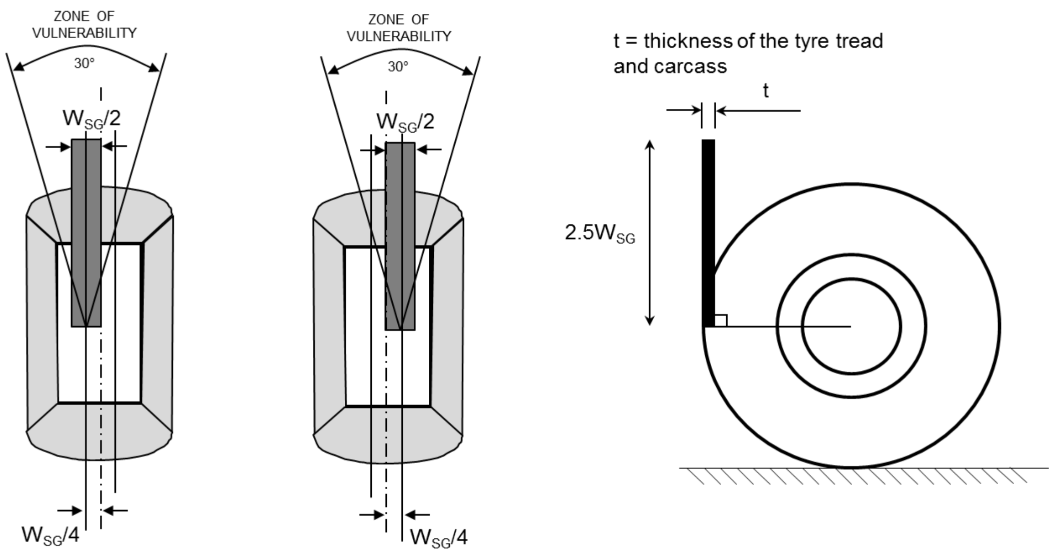
(ii) the failure of the retraction brake is independent from a flailing tyre strip event;

(iii) the retraction braking stops the rotation of the tyre before the trajectory of the flailing tyre strip can cause a hazard to the aircraft; and

(iv) the effect of a zero velocity retraction with the loose strip of tyre is assessed.

The strip has an initial speed equivalent to the minimum tyre speed rating certified for the aircraft. Allowance for rotation speed reduction during retraction may be substantiated by the applicant. For this threat the zone of vulnerability is 30°, as shown in Figure 3.

Figure 3 – Flailing Tyre Strip Threat



Model 4 — Tyre Burst Pressure Effect Threat Model

Applicability: landing gear retracting or landing gear retracted

1) In-flight tyre bursts with the landing gear retracted are considered to result from previous damage to the tyre, which could occur at any point on the exposed surface. A review of the known incidents shows that all cases of retracted tyre burst have occurred to main gear with braked wheels. This hazard is therefore considered to be applicable only to tyres mounted on braked wheels.

2) It is assumed that tyres do not release debris and consequential damage is considered to be caused only from the pressure effects of resulting gas jet ('blast effect'). The blast effect has been shown to differ between radial and bias tyres.

3) The tyre burst pressure is assumed to be 130 % of the maximum unloaded operational pressure, which is the unloaded tyre rated pressure reduced by a factor of 1.07 (safety factor required by CS 25.733(c)(1)).

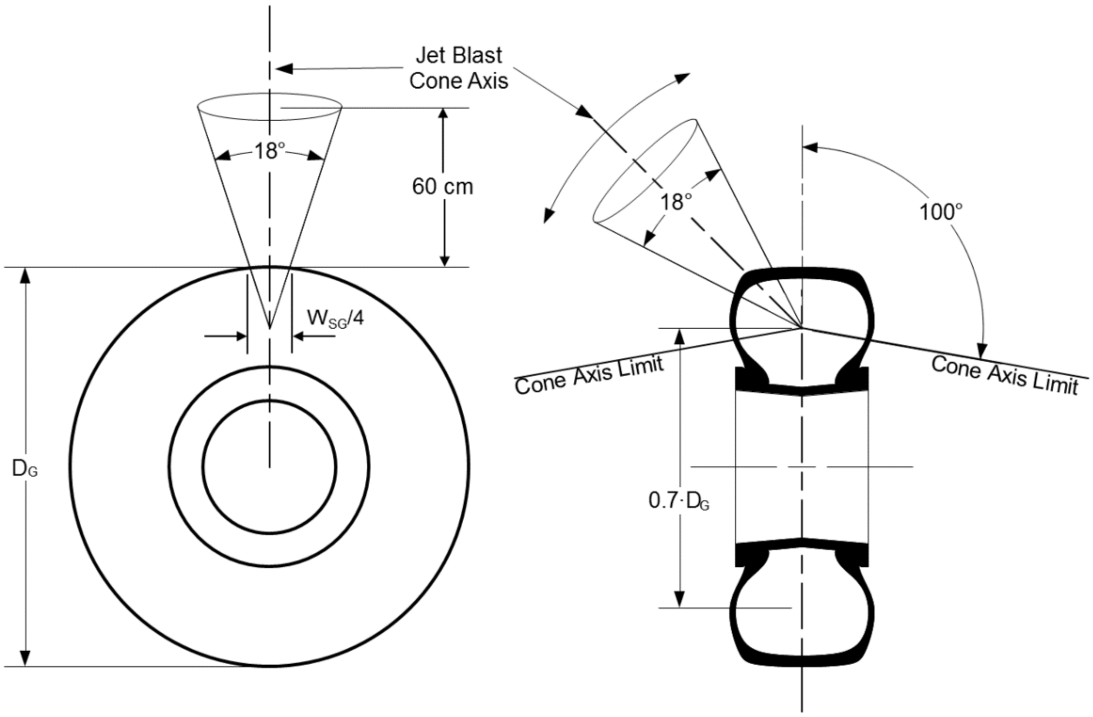
   Example: For an H44.5 × 16.5 – 21 26PR Tyre — The unloaded tyre rated pressure is 1 365 kPa (198 psig), so the maximum unloaded operational pressure is 1 365 / 1.07 = 1 276 kPa (185 psig), i.e. 1 377 kPa absolute pressure (199.7 psia); therefore the tyre burst pressure is 1 377 × 1.3 = 1 790 kPa absolute pressure (259.7 psia).

4) For bias tyres, the burst plume model shown in Figures 4a and 4b should be used, with the blast cone axis rotated over the tread surface of the tyre (± 100° as shown in Figure 4a). The pressure distribution is provided in Figures 4b and 4c.

5) For radial tyres, the burst plume model ('wedge' shape) is shown in Figures 4d and 4e. The pressure decay formula provided in Figure 4e below should be used. It provides the level of pressure as a function of the distance from the tyre burst surface.

6) The effect of the burst should be evaluated on structure and system items located inside the defined burst plume. In addition, there should be no effect detrimental to continued safe flight and landing due to the increase in pressure of the wheel well as a result of a retracted tyre burst.

Figure 4a – Tyre Burst Pressure Effect – Bias Tyre



Note: 'Grown dimensions' should be calculated for bias tyres using TRA formulas.

Figure 4b – Tyre Burst Pressure Effect – Bias Tyre

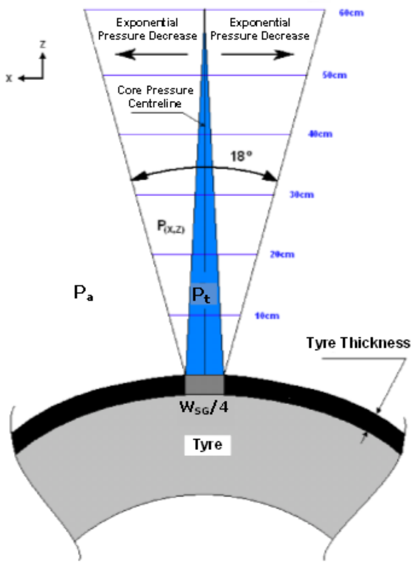
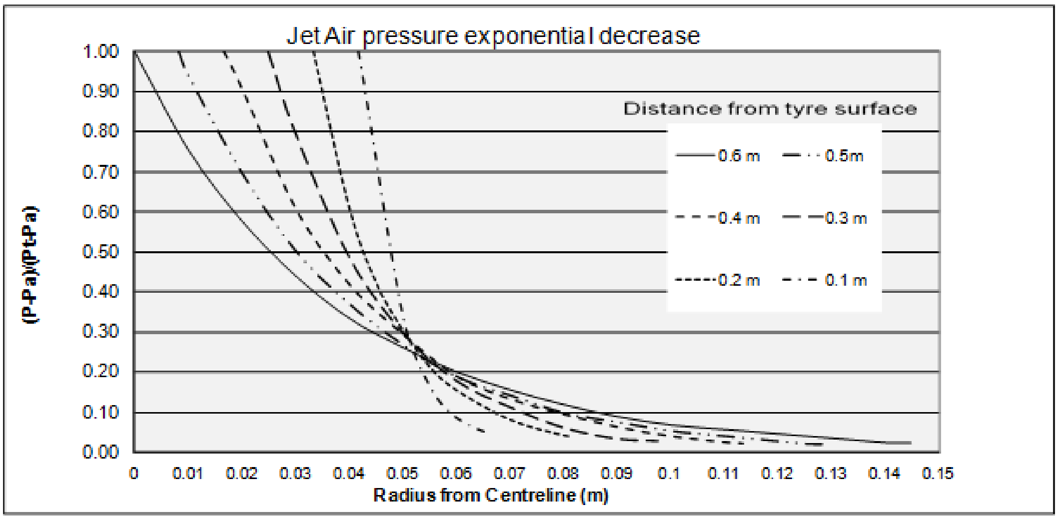


Figure 4c – Tyre Burst Pressure Effect – Bias Tyre

Air jet pressure distribution



Pa= Ambient pressure
P= P(x,z)= Pressure inside the cone as shown on Figure 2b
Pt= Tyre Burst pressure

Figure 4d – Tyre Burst Pressure Effect – Radial Tyre

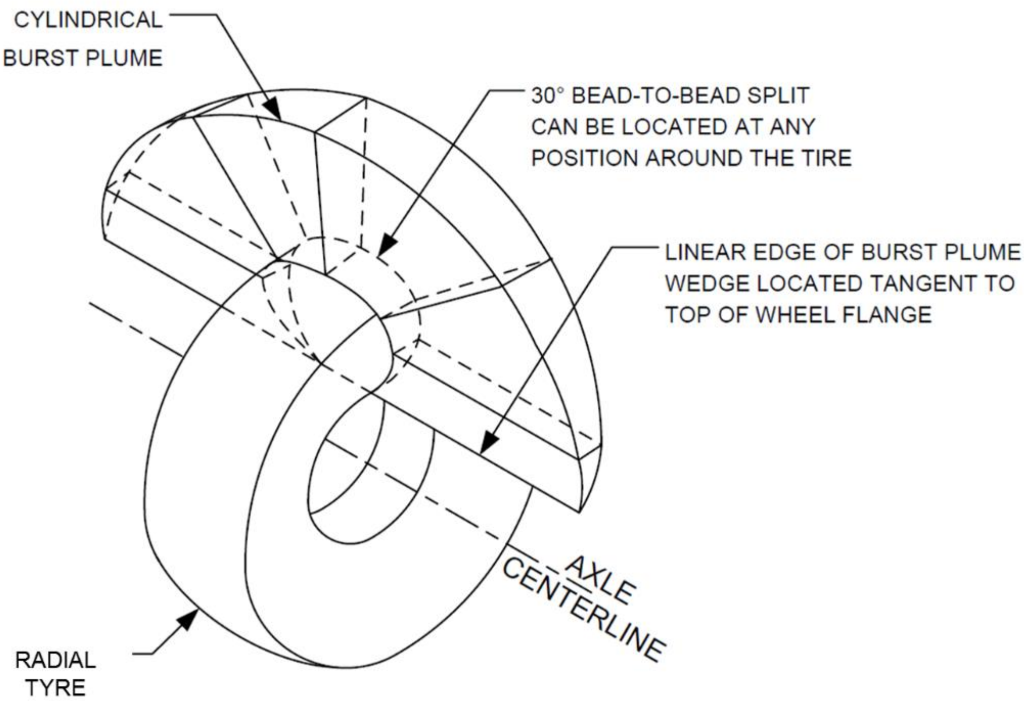
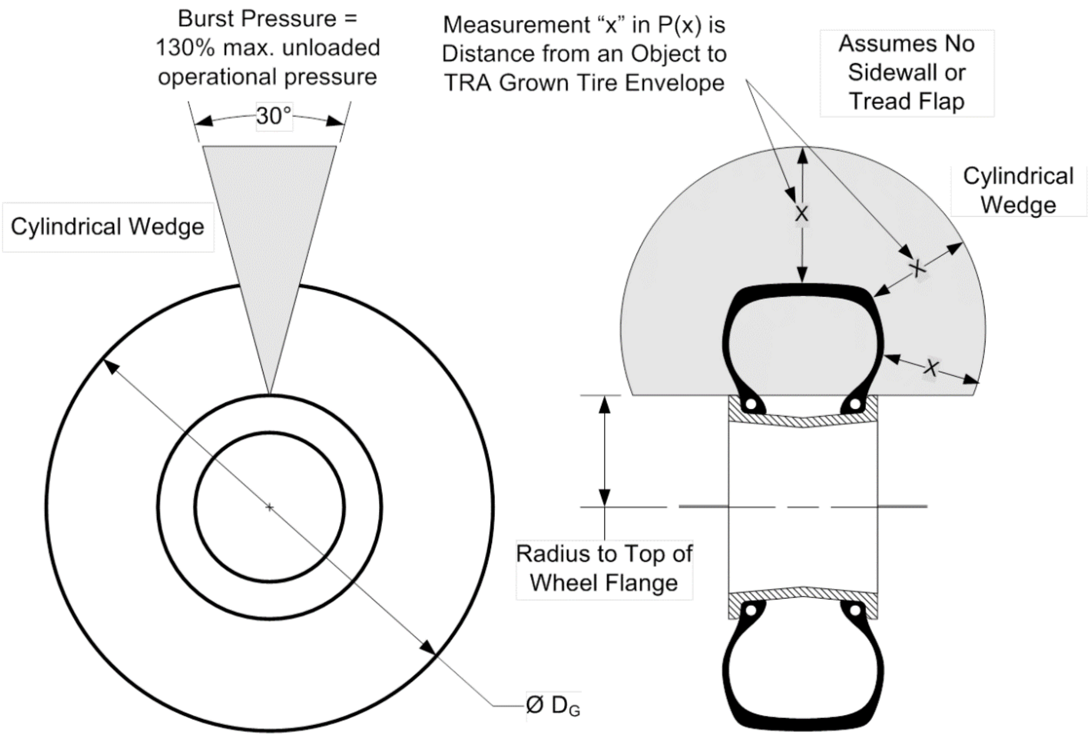


Figure 4e – Tyre Burst Pressure Effect – Radial Tyre



Radial Tyre Burst Pressure Decay Formula

$$P(x) = 0.5283 \cdot (P_t - P_0)\left[1.4 \cdot e^{-\left(\frac{\psi}{3}\right)\cdot x} + e^{-\psi \cdot x}\right] + P_0$$

Where:

$$\psi.x = \left(\frac{C_1}{\left(\frac{W_G}{in.}\right)^{C_2}} + C_3\right).\frac{x}{in.}$$

Or:

$$\psi.x = \left(\frac{C_1}{\left(\frac{W_G}{25.4mm}\right)^{C_2}} + C_3\right).\frac{x}{25.4mm}$$

and:

C_1 = 12.478,

C_2 = 1.222,

C_3 = 0.024

W_G = the Maximum Grown Section Width of the tyre [in or mm] as specified in the Tyre & Rim Association (TRA) designation for the tyre

P_t = Total or burst pressure [psia or bar]

P_0 = Ambient pressure [psia or bar]

x = Distance from object to grown tyre surface [in or mm]

If P(x) > Pt then P(x) = Pt; otherwise P(x) = P(x).

[Amdt 25/14]

CS 25.735 Brakes and braking systems

ED Decision 2013/033/R

(See AMC 25.735)

(a) *Approval.* Each assembly consisting of a wheel(s) and brake(s) must be approved.

(b) *Brake system capability.* The brake system, associated systems and components must be designed and constructed so that:

(1) If any electrical, pneumatic, hydraulic, or mechanical connecting or transmitting element fails, or if any single source of hydraulic or other brake operating energy supply is lost, it is possible to bring the aeroplane to rest with a braked roll stopping distance of not more than two times that obtained in determining the landing distance as prescribed in CS 25.125.

(2) Fluid lost from a brake hydraulic system following a failure in, or in the vicinity of, the brakes is insufficient to cause or support a hazardous fire on the ground or in flight.

(c) *Brake controls.* The brake controls must be designed and constructed so that:

(1) Excessive control force is not required for their operation.

(2) If an automatic braking system is installed, means are provided to:

(i) Arm and disarm the system, and

(ii) Allow the pilot(s) to override the system by use of manual braking.

(d) *Parking brake.* The aeroplane must have a parking brake control that, when selected on, will, without further attention, prevent the aeroplane from rolling on a dry and level paved runway when the most adverse combination of maximum thrust on one engine and up to maximum ground idle thrust on any, or all, other engine(s) is applied. The control must be suitably located or be adequately protected to prevent inadvertent operation. There must be indication in the cockpit when the parking brake is not fully released.

(e) *Anti-skid system.* If an anti-skid system is installed:

(1) It must operate satisfactorily over the range of expected runway conditions, without external adjustment.

(2) It must, at all times, have priority over the automatic braking system, if installed.

(f) *Kinetic energy capacity –*

(1) *Design landing stop.* The design-landing stop is an operational landing stop at maximum landing weight. The design landing stop brake kinetic energy absorption requirement of each wheel, brake, and tyre assembly must be determined. It must be substantiated by dynamometer testing that the wheel, brake and tyre assembly is capable of absorbing not less than this level of kinetic energy throughout the defined wear range of the brake. The energy absorption rate derived from the aeroplane manufacturer's braking