U.S. Department
of Transportation

Federal Aviation Administration

Advisory Circular

Subject: FLIGHTDECK PENETRATION RESISTANCE

Date: 1/10/02

AC No: 25.795-2

Initiated by: ANM-110

1. PURPOSE. This advisory circular (AC) sets forth an acceptable means, but not the only means, of demonstrating compliance with the provisions of the airworthiness standards for transport category airplanes related to the airplane design for flightdeck penetration resistance. Terms used in this AC, such as "shall" or "must," are used only in the sense of ensuring applicability of this particular method of compliance when the acceptable method of compliance described herein is used. While these guidelines are not mandatory, they are derived from extensive Federal Aviation Administration (FAA) and industry experience in determining compliance with the pertinent regulations.

2. RELATED DOCUMENTS.

a. Title 14, Code of Federal Regulations (14 CFR) part 25, §§ 25.365, 25.771, 25.772, 25.795, 25.803 and 25.853.

b. Title 14, Code of Federal Regulations (14 CFR) part 91, § 91.11.

c. Title 14, Code of Federal Regulations (14 CFR) part 121, §§ 121.313 and 121.587.

d. International Civil Aviation Organization (ICAO) Annex 8 to the Convention on International Civil Aviation, entitled "Airworthiness of Aircraft."

3. REFERENCES.

a. Title 14, Code of Federal Regulations (14 CFR) part 25, § 25.795d.

b. SRI International, Fourth Workshop on Uncontained Engine Debris Characterization, Mitigation and Modeling, Aircraft Catastrophic Failure Prevention Program, May 2-4, 2000.

c. National Institute of Justice, Ballistic Resistance of Personal Body Armor, NIJ Standard 0101.04, Office of Science and Technology, Washington, D.C. 20531, September 2000.

4. DEFINITIONS. Terms that are unique to ballistic testing and firearms, or may not be in general use, are as follows:

a. Angle of Incidence. The angle between the line of flight of the bullet and the perpendicular to the front surface of the barrier (see Figure 1).

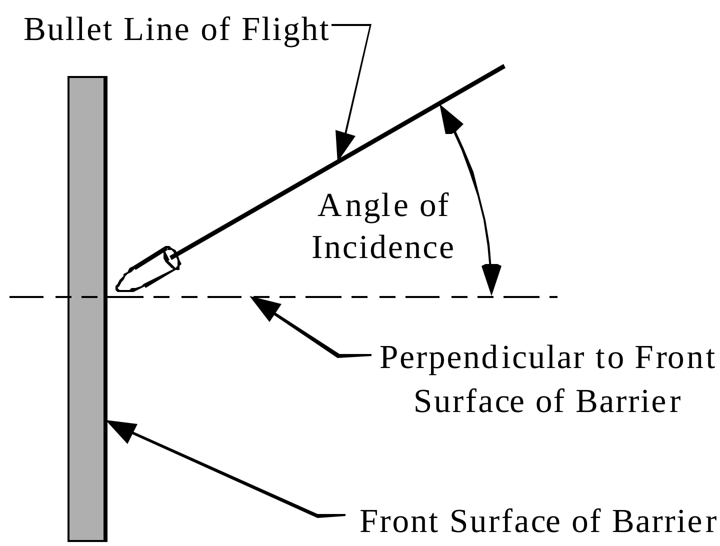

Figure 1. Angle of Incidence

b. Full Metal Jacketed Bullet (FMJ). A lead core bullet completely covered with a copper alloy jacket (approximately 90 percent copper and 10 percent zinc) except for the base. Total Metal Jacket (TMJ), Totally Enclosed Metal Case (TEMC), and other commercial terminology for bullets with electro-deposited copper and copper alloy coatings are considered comparable to Full Metal Jacketed (FMJ) bullets.

c. Hazardous Trajectory. A shotline, from any ballistic threat, originating from any passenger-accessible compartment that passes through the flight-critical zone defined by flightcrew positions, flight-critical instrumentation or flight-critical systems within the flightdeck. See Figure 2.

d. Jacketed Hollow Point Bullet (JHP). A lead core bullet with a hollow cavity or hole located in the nose of the bullet and is completely covered with a copper-alloy jacket (approximately 90 percent copper and 10 percent zinc), except for the hollow point.

e. Penetration, Complete. Full passage of a bullet or bullet fragment through a test panel without being stopped, i.e., brought to zero velocity.

f. Penetration, Partial. An impact to a test panel in which the bullet and all of its fragments are stopped. Any portion of the bullet may protrude.

g. Reference Bullet Velocity. The designated impact velocity.

h. Round Nose Bullet (RN). A bullet with a generally blunt or rounded nose that may have a small flat surface at the tip of the nose.

i. Test Panel. The protective barrier, consisting of ballistic resistant materials, that is representative of production structure that shields the flightdeck from potential ballistic threats and is used to demonstrate actual capability in resisting projectile penetrations. It has representative arrangements and features, as they will appear on the airplane.

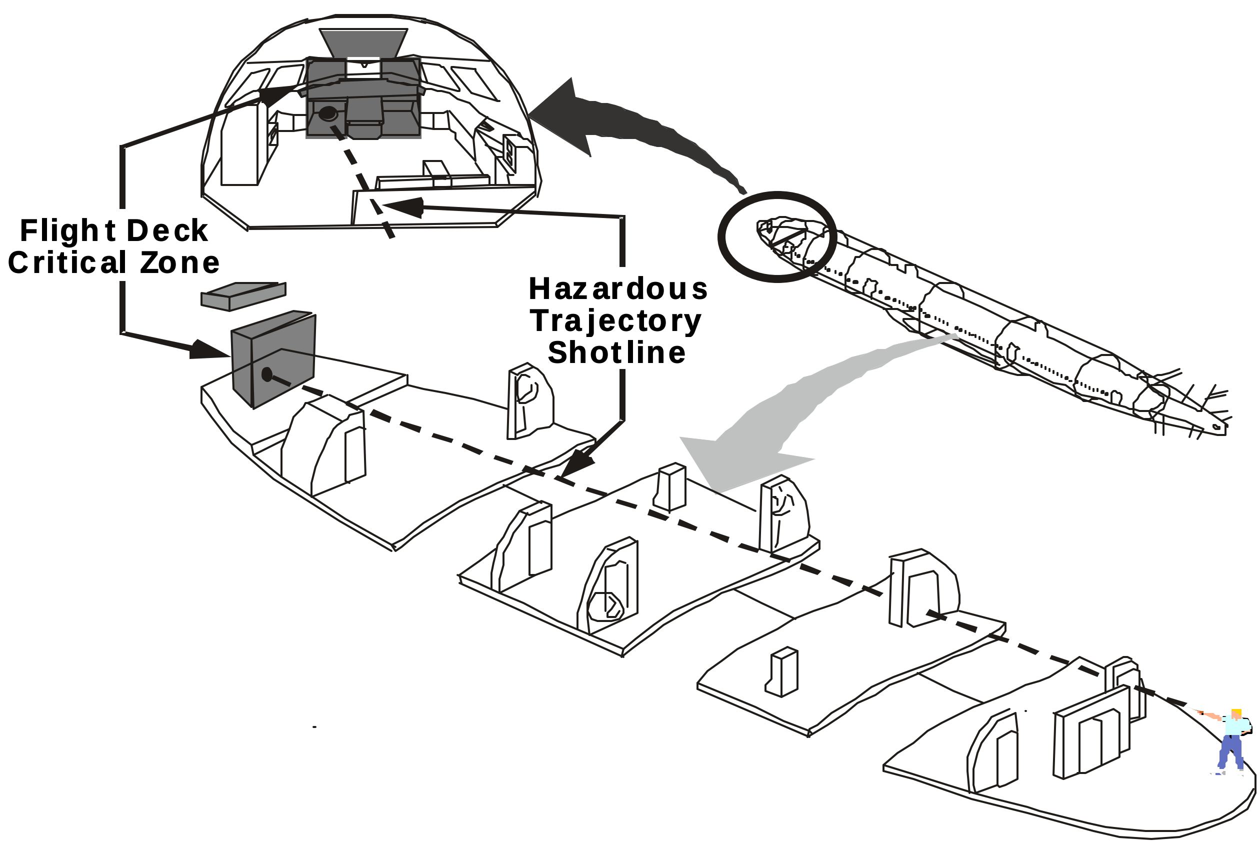

Figure 2. Example of a Hazardous Trajectory (Shotline Intersects Within the Critical Zone of the Flight Deck)

5. BACKGROUND.

a. Historical Events. Numerous hijackings and armed confrontations with passengers have occurred aboard commercial transport flights. These incidents have usually involved the use of various types of weapons, including handguns, knives, hand grenades and explosives. In some cases, the weapons were actually used or discharged during flight.

b. Vulnerability. Although inherent features of airplanes provide high levels of safety, the flightdeck remains comparatively vulnerable to incidental weapon attacks. Not only are pilots susceptible to trauma but the potential loss of critical flight instrumentation and control is also of concern. The disabling of critical systems from a single ballistic penetration is achievable with the concentration of most systems control within a small sector of the flightdeck. Electronic displays of basic flight information are similarly vulnerable.

c. Active Measures. To counter weapon threats and intentional acts of destruction, measures have been taken to prevent the introduction of dangerous objects aboard transport flights. Recognizing that these efforts may never be fully effective, the International Civil Aviation Organization (ICAO) sought to improve the survivability of airplanes in the event that these dangerous objects escape detection and are employed during flight. A series of rules, established in Annex 8 to the Convention of International Civil Aviation, entitled "Airworthiness of Aircraft," were incorporated that addressed these concerns.

6. OBJECTIVE. Regions of the flightdeck that are vulnerable to ballistic threats originating from passenger compartments will be protected from small-arms projectiles and fragment debris from hand grenades (kinetic-energy weapons).

a. The intent is to ensure that safe flight and landing is not compromised through discharges of a firearm or fragmenting device.

b. Features of a door, such as decompression panels, louvers, doorknobs, latches, hinges, lugs and peepholes, do not require testing if it can be shown that their failure would not degrade the penetration resistance of the door. Such a feature would be one that is not on a hazardous trajectory, as defined above, or that, if it fails, does not create an opening into the flightdeck that is on a hazardous trajectory.

c. Joints between panels should not have gaps, or should be protected from penetration by, for example, an overlapping of protective material.

7. PRINCIPLES AND TECHNIQUES.

a. Several materials and concepts, designed to defeat ballistic threats, have been evaluated. Useful materials include metallic alloys, ceramics, polymers, strong fibers and composites. For lightweight and relatively low-energy applications, strong fibers, sometimes coated in a matrix material, may offer the best protection.

b. For woven fabrics, mesh or tightness of weave (yarns/inch) also has an effect on performance but limited data suggest that this effect is minor when compared against specific energy absorbed (energy/areal density).

c. The size and shape of the projectile also affects material response. The larger the fragment, the more fibers that have to be broken before penetration can occur.

d. The technique used to secure the material to its supports can have a significant effect on energy absorption. A material entirely glued to a surface or encased in a resin matrix is normally unable to yield or dissipate as much energy as a material that is only restrained at its outer boundaries. The data even suggest that restraining the material only at opposite ends instead of all four sides is appreciably better. The more flexible the attachment, the better able the material is to stretch and redistribute loads over larger areas and dissipate more energy through friction and deformation. Increasing distance between attachment points has also been shown to be beneficial since more material deforms and energy can dissipate over larger areas.

e. Combining multiple layers of material can also improve energy absorption more than the sum from individual layers. The interaction of overlaid materials disperses additional energy through friction.

f. It would also be expected that two fragments with the same basic shape and of equal energies but with different masses would perform differently. The higher velocity fragment would be more easily stopped than the slower fragment. This is expected because of higher momentum exchange to the material (energy losses from accelerating the material) and higher strain rates, which normally delay material failures.

g. While laboratory tests of ballistic fabrics soaked in water have displayed reductions in ballistic resistance as compared with identical dry fabrics, the flightdeck operates within normal humidity ranges, so testing the installed shielding in a soaked condition is not required.

h. Based on material selection, configuration and installation arrangement, areal densities less than one pound per square foot should be achievable for shielding protection against the defined threat in this AC.

i. A series of tests will require projectile impacts at both perpendicular and at an angle of incidence to the surface because most random shots would be unlikely to hit exactly perpendicular to the surface. Some materials offer lower protection by as much as 20 percent when a bullet strikes at an angle. The shielding must provide the minimum level of protection, regardless of the angle of impact.

j. Limited studies of ballistic-resistant material capabilities under extended periods of use were conducted in 1983. Some of the material tested had been in service for more than 8 years. This testing and a 1986 study by NIJ (Ballistic Tests of Used Body Armor) found that age alone does not degrade the ballistic properties of such armor. Material manufactured in 1975 that remained in inventory without issue exhibited ballistic-resistant properties identical to those at the time of manufacture. Both research studies included body armor that had been in use for as long as 10 years and had ballistic properties that were indistinguishable from those of unused armor manufactured at the same time. Age is therefore not considered to be a significant factor for ballistic resistance.

8. COMPLIANCE CRITERIA.

a. Standardization. The National Institute of Justice (NIJ), a research, evaluation and development branch under the U.S. Department of Justice, advanced a voluntary national procedure to provide minimum performance requirements for soft body armor. The regulatory requirements and means to demonstrate compliance described in this AC were based, in part, on this nationally recognized standard and are found in NIJ Standard-0101.04. This is the fourth revision since its original release in March 1972, and was issued in September 2000. Although NIJ may continue to revise that standard, the criteria in this AC are based on the NIJ Standard-0101.04.

b. Applicability. The NIJ Standard-0101.04 specifically addresses protection of the torso from ballistic threats. Since the intent of this AC is to protect the flightdeck and not body torsos, various requirements within the NIJ standard are not integrated into this AC. Specific guidance to achieve compliance is found within this AC.

c. Classification. The NIJ standard identifies seven levels of protection through a type classification. Type IIIA is an acceptable level to show compliance with § 25.795 (a)(1). This level offers protection against most handguns and is considered to provide an adequate level of protection from fragmentation devices as well as the Type I, IIA, and II threats. Demonstration of penetration resistance for Type IIIA rounds is accomplished with two different projectiles.

(1) Demonstration Projectile #1. A 9 mm full metal jacket, round nose (FMJ RN) bullet with nominal mass of 8.0 g (124 grain) and reference velocity 436 m/s (1,430 ft/s)

(2) Demonstration Projectile #2. A .44 Magnum, jacketed hollow point (JHP) bullet with nominal mass of 15.6 g (240 grain) and reference velocity 436 m/s (1,430 ft/s)

9. COMPLIANCE DEMONSTRATION.

a. Compliance may be shown by analysis, tests, or by comparison with previously approved configurations. If tests are used to demonstrate compliance, specimens must be representative of the arrangements used on the airplane. All configurations must be tested, unless the performance of the configurations not tested is rationally shown to be equal or better. Previously approved test data may be used as a basis for compliance for other airplane configurations provided that their applicability is demonstrated in a rational manner. However, features such as decompression panels, louvers, doorknobs, latches, hinges, lugs and peepholes should be addressed as discussed in paragraph 6c.

b. Validation tests are not required if the ballistic performance of the configuration will meet certification requirements based on comparative analysis, provided that the methods used are shown to be rational. In order to demonstrate compliance without a test, the following factors must be assessed to show that the fabrication and/or installation have not degraded the material performance:

(1) Material properties.

(2) Fabric weave (direction and density) – if applicable.

(3) Material thicknesses and interactions (multiple plies).

(4) Attachment arrangements and supporting structure.

(5) Energy absorption methods.

(6) Fabrication of the surfaces affected (e.g., door, bulkhead etc.).

c. <u>Test Procedures</u>. This procedure provides an acceptable method to demonstrate adequate protection for the flightdeck against ballistic threats. The tests demonstrate the ability of the shield to prevent bullet penetrations with a pass/fail criterion. In order to pass, all portions of the projectile must be stopped by the shielding on each of the required tests. Partial penetrations of the bullet through the shielding are acceptable.

(1) <u>Hand loads</u>. Hand-loaded ammunition may be used on any of the tests. Adjustments are normally made to powder quantity to assure velocity requirements are met.

(2) <u>Test Barrels</u>. Use of test barrels or actual weapons appropriate for the ammunition are acceptable provided that impact locations, projectile orientations and impact velocities can be maintained.

(3) <u>Ambient Test Conditions</u>. Ambient conditions of the test range will be maintained at:

(a) Temperature: 21° C ± 2.9° C (70° F ± 5° F); (b) Relative humidity: 50% ± 20%;

(c) No additional environmental effects need be considered.

(4) <u>Test Specimens</u>. Test specimens shall be manufactured using the materials and manufacturing processes used for production parts. A sufficient number of specimens will be

provided to accomplish all tests. They will be conditioned to ambient conditions for at least 24 hours prior to testing unless the materials used are shown to be insensitive to variations in temperature and humidity.

(5) Timing Screens. Projectile impact velocities will be measured on every test. Any system that can measure velocities to within 3 m/s (10 ft/s) are acceptable. Individual recording devices must be capable of discriminating to 0.3 m/s (1.0 ft/s) or 0.1 microseconds (10^{-7} seconds). Recommended velocity measuring equipment includes:

(a) Photo electric light screens;

(b) Printed make circuit screens;

(c) Printed break circuit screens; or

(d) Ballistic radar.

(6) Timing Screen Arrangement. The first timing screen will be placed a minimum of 2 m (78.7 in) from the end of the test barrel (see Figure 3). The second screen will be placed 1.5 m (59.05 in) ± 6 mm (0.24 in) from the first screen. The test specimen will be placed 5 m (196.85 in) ± 25 mm (1.0 in) from the end of the test barrel.

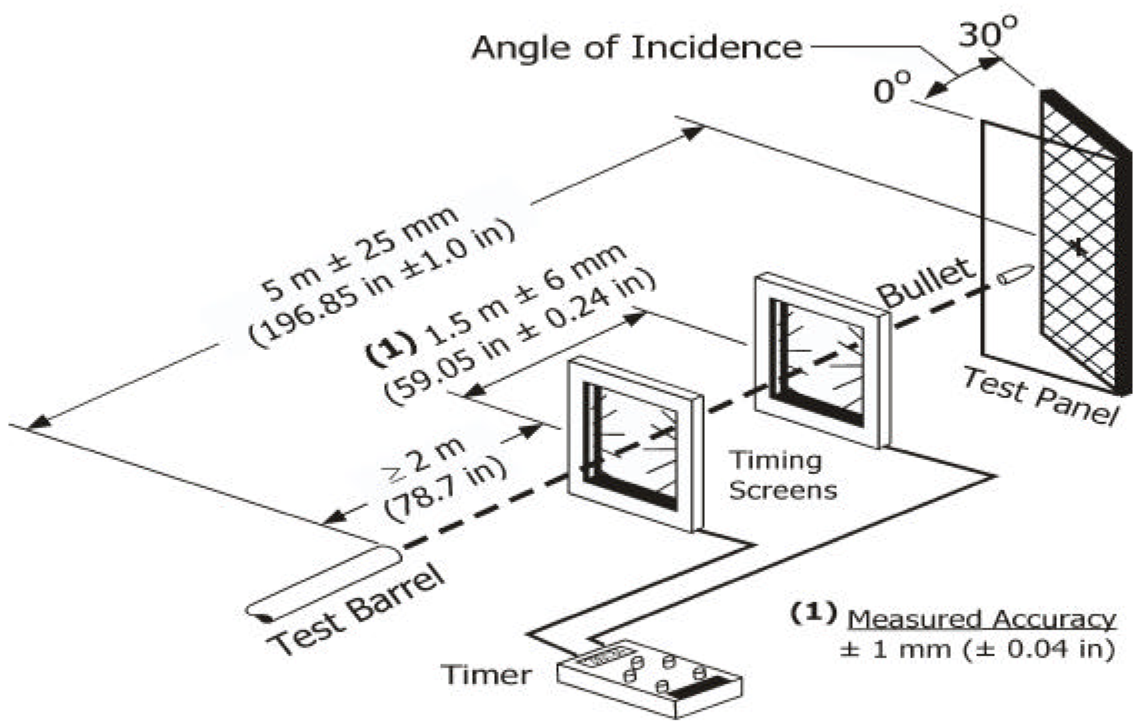

Figure 3. Test Arrangement for Ballistic Test Panels

Although the spacing between the gun barrel and the test panel is substantial (5 meters), this is neither indicative nor representative of the distances that may be experienced from an actual inflight incident. Design considerations must assume that weapon use may occur at distances ranging from point-blank range to the length of the passenger cabin. The test evaluation distances were selected as compromises for competing requirements.

(7) Test Panels. Through-thickness construction of the test panels should not be greater than the minimum configuration to be used in service. The test panels may be simplified with respect to peripheral size, geometry and boundary conditions. It must be shown that the simplifying assumptions are rational and lead to a conservative representation when compared to the actual airplane configuration. The test-panel fixture should not provide a significant increase in damping or energy absorption compared to the airplane configuration. Six impact sites will be identified on the test panel for the first ammunition type. These sites will be uniformly spaced throughout the panel with no site closer than 76 mm (3.0 in) from center of impact to any edge of the protection shield and 51 mm (2.0 in) measured center-to-center between any two impact sites. If space is available on the test panel, using the same criteria, the next six sites for the second ammunition type can be identified for the second test series. Otherwise, a new test panel will be required. If the mechanism for stopping projectiles is lost after any shot, replacement panels may be used to complete the test series. However, the same relative impact locations must continue to be employed, as previously assigned. The test panels will be tested in dry conditions.

(8) Test Shots. Table 1 provides the test conditions that are sufficient to demonstrate compliance. The shielding devices are required to prevent penetration from the impact of six bullets at the designated velocities and locations for two ammunition types. Two of the impacts in each six-shot sequence must be at a 30 degree angle of incidence. After each shot, the panel will be inspected to determine if the projectile was fully arrested and either a pass or failure will be recorded. The velocity will also be computed and recorded. If the velocity is less than the minimum acceptable or the impact site is outside of the allowable limits, a retrial may be necessary. The projectile may be removed, if desired, before subsequent shots.

(9) Witness Sheet. A witness sheet of suitable material should be placed six inches behind the test specimen for verification that there was not complete penetration of the sample by the projectile or fragments.

Table 1. - Performance Test Summary

Test Round	Test Bullet	Bullet Weight	Bullet Diameter	Reference Velocity	Hits at 0° Angle of Incidence	Hits at 30° Angle of Incidence	Shots per Panel	Total Shots Required
1	9 mm FMJ RN	8.0 g (124 grains)	9 mm (.355 in)	436 m/s (1430 ft/s)	4	2	6	12
2	.44 Magnum JHP	15.6 g (240 grains)	10.9 mm (.429 in)	436 m/s (1430 ft/s)	4	2	6	

10. PASS/FAIL CRITERIA. To be a valid shot, several criteria must be met. The bullet must impact the panel at an angle of incidence ± 5 degrees from the intended angle of incidence, at a yaw angle (of the bullet) within ± 5 degrees, at an impact velocity within ± 9.1 m/s (30 ft/s) of the reference velocity and no closer to an edge or adjacent impact site than given in paragraph 9a(7). If all conditions are met and the impact velocity equals or exceeds the velocity limit without penetration, it is considered a pass. If all conditions are met except the impact velocity occurs at or less than the velocity limit, with penetration, it is considered a failure. If all conditions are met but penetration occurs above the velocity limit, a retrial may be performed without making any design changes.

/s/

VI LIPSKI
Manager, Transport Airplane Directorate,
Aircraft Certification Service, ANM-100