Appendix C
Materials Used in Aircraft

C.1 Introduction

Materials used in aircraft are roughly the same regardless of the type of aircraft involved (normal and transport category airplanes and/or rotorcraft). The various Federal Aviation Regulations (FARs) refer mostly to FAR 25 for flammability requirements. For simplicity, this discussion will, therefore, refer only to FAR Part 25.

C.2 Aircraft Seats

Aircraft seats use a wide variety of nonmetallic materials in the constructions of the components that make up a complete seat. These components can be grouped into five basic areas (see figure C-1): foam cushions, upholsteries, fire blockers, plastic moldings, and structure. All nonmetallic seat parts must meet FAR 25.853(b). The cushions, which includes the foam, upholstery, and fire blocker (if used), must also meet FAR 25.853(c).

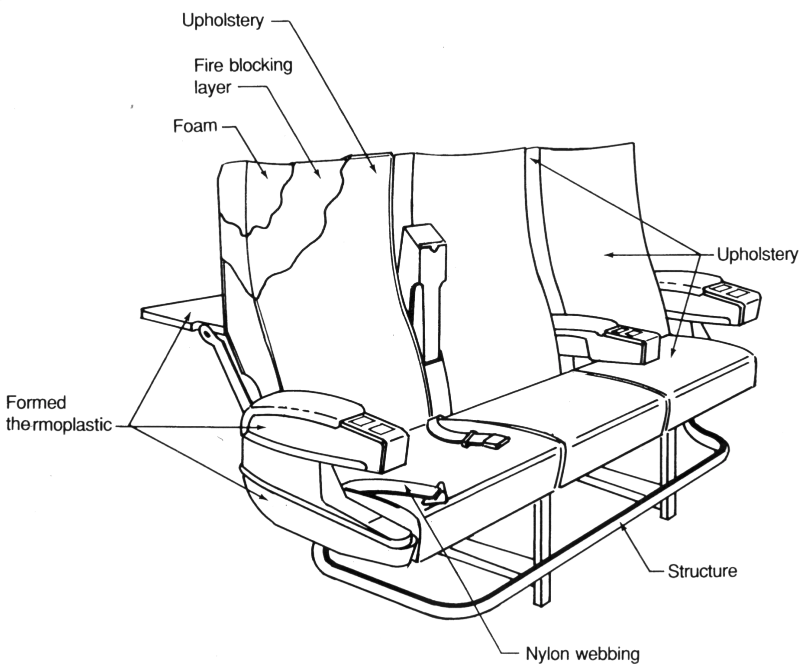


Figure C-1. Typical Seat Installation

C.2.1 Foam Cushions

Selection of foams for seats is based on requirements such as wear, comfort, flotation, flammability, and others. To meet these requirements, many different foams of various densities are used. The foam in the cushions is either molded to the final shape or cut from existing foam stock and bonded together with adhesives. Open cell urethane foams are most commonly used with densities as low as $1.98/ft^3$. If the cushion is to serve as a flotation device in emergency situations, the foam must be closed cell; polyethylene foams are often used for this. Neoprene, silicone, and modified urethane foams can be used for cushions to meet FAR 25.853(c) without a fire-blocking textile. They may also be used as fire blockers over conventional foams. The densities of these foams have a range of 3 to 4 lb/ft^3.

C.2.2 Upholsteries

Typical dress cover fabrics include wool, wool/nylon blends, leather, fire-retarded (FR) polyester, FR nylon, and vinyl. Wool blends with an FR treatment, typically a zirconium type, are by far the most common type of upholstery in use and have proven to be one of the most reliable in passing FAR 25.853(b) and FAR 25.853(c). Many nondecorative fabrics are also used in seat installations; FR cotton muslin is used as a slip cover to allow easier installation of the dress cover.

C.2.3 Fire-Blocking Textiles

The use of fire-blocking textiles was required by FAR 121, Amendment 184, which required that seat cushions comply with FAR 25.853(c). To meet this regulation, textiles made of synthetic fibers, such as polybenzimidazole (PBI), aromatic polyamides, and glass, are woven or felted and used to encapsulate the foam. The weight of the fire-blocking textile required depends primarily on the foam construction and type with lower density foams normally requiring heavier fire-blocking layers.

C.2.4 Plastic Molding

Aircraft seats employ a wide variety of plastic moldings for items such as decorative closeouts, trim strips, food trays, and arm rests. Polycarbonate, acrylonitrile-butadiene-styrene (ABS), and decorative vinyls are commonly used for these purposes.

C.2.5 Structure

Most seat structures are made of aluminum; however, some manufacturers have introduced carbon composite structures to reduce weight.

C.3 Insulating Materials

The entire pressurized section of the aircraft is completely lined with thermal/acoustical insulation, which is by far the largest volume of nonmetallic material in an aircraft. The acoustical requirements for the insulation are more demanding than the thermal requirements. The insulation blanket construction used consists of a batting surrounded by a protective cover; however, in some applications, where the insulating material consists of foams or felts, a separate cover is not used. Insulation batting and covers are required to meet FAR 25.853(b).

C.3.1 Batting

Most of the thermal/acoustical insulation used is fibrous glass batting that is 0.42 to 0.6 lb/ft^3 in density and held together with a water-repellent treated phenolic binder. The diameter of the glass fiber is very small, approximately 0.0006 inch for acoustical reasons. The material easily meets FAR 25.853(a) and FAR 25.855(a). In other insulation applications (e.g., used for air ducting), foams (e.g., urethane and polyimide) and felts (e.g., aromatic polyamides) are extensively used. In higher temperature areas, fibrous glass batting with a silicone binder (for temperatures up to 700°F) and ceramic batting (for temperatures up to 2,000°F) are used. Areas of application include engine pylons, nacelles, power units, and engine bleed air ducting.

C.3.2 Insulation Covers

The main reasons for covering insulation batting are to hold it in place and to keep out contaminants such as dust and fluids, especially water. Very thin plastic films (0.5 to 2 mils) of polyester or polyvinyl fluoride reinforced with nylon yarn are used extensively due to their light weight and good tear resistance. In areas that are subject to abuse, lightweight, abrasion-resistant coated fabrics such as vinyl-coated nylon and vinyl-coated fiberglass are used. Areas subject to higher temperature require the use of silicone-coated fiberglass, metallized fiberglass, or ceramic covers.

C.3.3 Insulation Installation

Insulation is installed using a variety of attachments, including hook and loop tape (Velcro), nylon fasteners, snaps, and splicing tapes.

C.4 Interior Panel Structures

Although a few monolithic laminate panels are used, most panels used in airplane interiors are sandwich structures. This type of construction is preferred for its high strength and stiffness to weight ratio. These panels are made basically of face sheets, adhesives, core, and decorative coverings, with small variations that depend on the requirements for the individual application. Typical panels are shown in figure C-2. These panels are used for ceilings, galleys, lavatories, sidewalls, baggage racks, floors, partitions, and closets. All panels used for these applications must meet FAR 25.853(a) and (a-1).

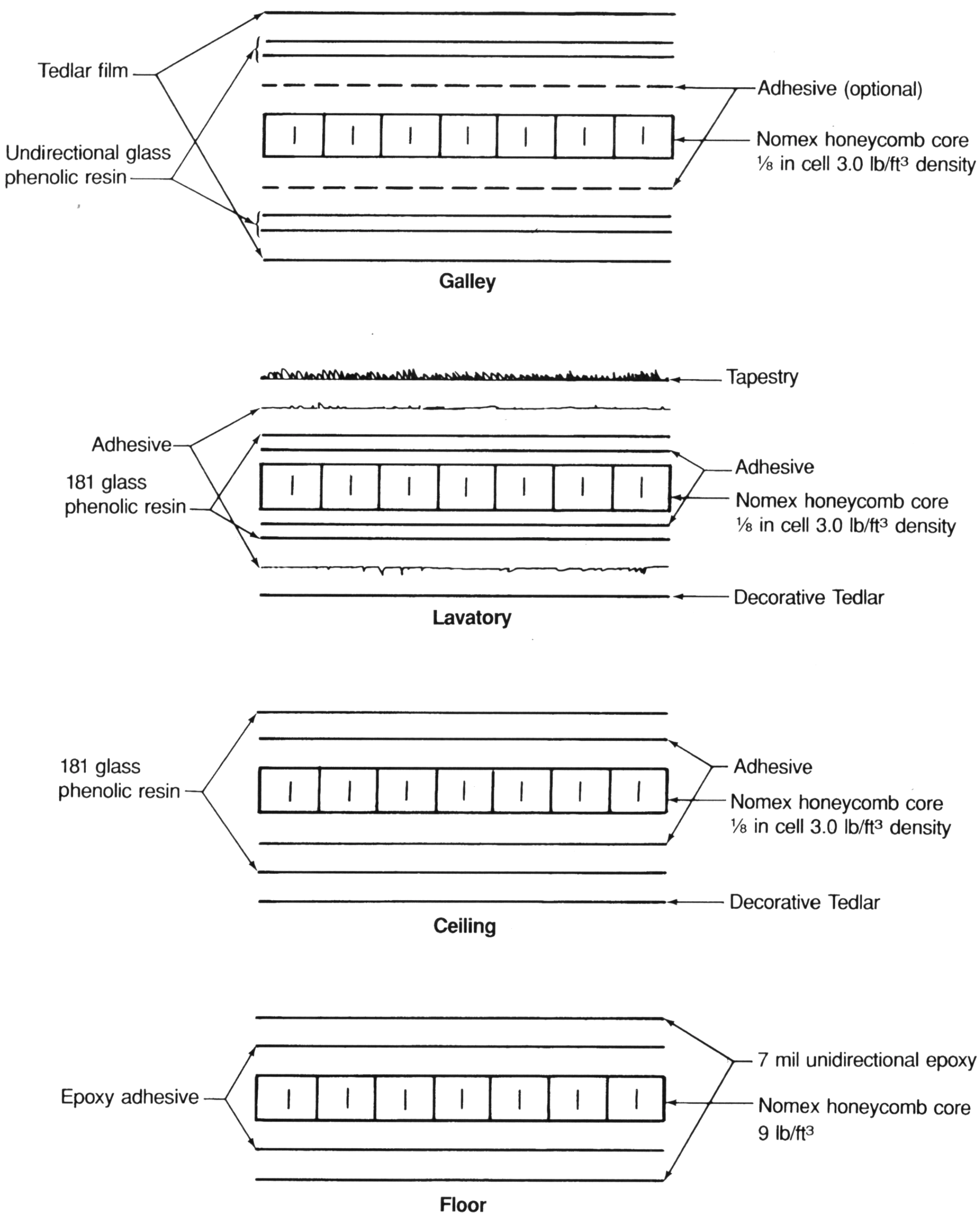


Figure C-2. Typical Panel Installation

C.4.1 Face Sheets

All panel faces consist of a resin system and a fiber reinforcement.

C.4.1.1 Fiber Reinforcement

The fiber reinforcement can either be unidirectional or woven. Fiberglass, aromatic polyamides, and graphite/carbon are used due to their high strength to weight ratio and good fire resistance. Fiberglass is the most common due to its low cost. Aromatic polyamides and carbon fibers are much higher in cost but their very high strength to weight ratio make them attractive in many applications.

C.4.1.2 Resin System

Epoxy resin systems were widely used in the middle 1960s. Later, beginning in the 1970s, phenolic resin systems began to replace epoxies because of their superior fire resistance and low smoke emissions, despite that phenolics generally are lower in strength. Today, the most prevalent resin systems are phenolic. Epoxy is still used in certain applications where strength considerations are important and/or where competing phenolic systems are not available.

C.4.2 Core

The core in a sandwich panel is most often a honeycomb structure to achieve the best physical properties at the minimum weight. Aluminum honeycomb has been used in cabin interiors; however, the most common type honeycomb is an aramid-based paper coated with a phenolic resin to stabilize the paper. Aramid honeycomb ranges in density from 1.5 pounds per cubic foot for lightweight ceiling panels to 9 pounds per cubic foot for floor panels; cell sizes range from 1/8 inch to 3/4 inch. Aramid honeycomb provides good fire resistance and can easily meet FAR 25.853(a) without face sheets. Other types of core materials that have been used include polyurethane, polyvinyl chloride, polyimide foams (to reinforce edges and fastener points), and balsa wood (for floor panels in passenger cabins and cargo holds).

C.4.3 Adhesives for Bonding Face Sheets to Core

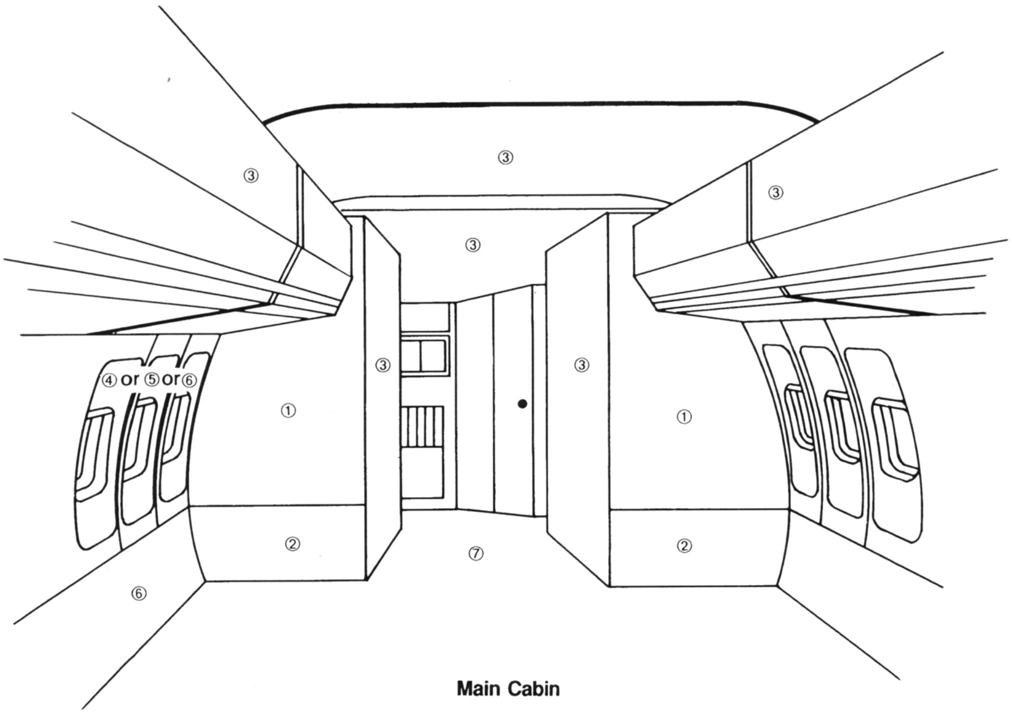
Epoxy and modified phenolic film adhesives are used to bond face sheets to the core. Some face sheets employ a modified resin to allow bonding directly to the core and do not require a separate adhesive film.

C.4.4 Decorative Coverings for Panels

All interior panels have a decorative covering on surfaces that are visible to passengers. Decorative plastics, paint, wainscoting, and tapestries all serve both aesthetic and functional purposes. See figure C-3 for a description of decorative coverings used in a typical main cabin of an aircraft.

C.4.4.1 Plastic Laminates

Most surfaces that are in direct contact with passengers and crews or surfaces that require a lightweight cover have decorative plastic laminates. Galley and lavatory surfaces that face the aisle, ceilings, baggage racks, lavatory interiors, and door liners are typical applications for decorative plastic laminates. In high use areas, vinyls have been applied because of their good abrasion resistance. Surfaces that expect less abuse employ polyvinyl fluoride (PVF) or PVF/vinyl combinations. These materials have good cleanability and colorfastness. Many of the new decorative Tedlar laminates exhibit very low heat release, making them ideal for many interior surfaces that are required to meet FAR 25.853(a-1).



Main Cabin

① Panel construction with tapestry cover.
② Panel construction with wainscot cover.
③ Panel construction with decorative plastic laminate.
④ Formed thermoplastic or laminate.
⑤ Formed aluminum with decorative plastic laminate.
⑥ Composite laminate with wainscot cover.
⑦ Panel construction with carpet cover.

Figure C-3. Typical Main Cabin

C.4.4.2 Decorative Textiles

Surfaces that face the passengers on galleys, lavatories, closets, and partitions are typically covered with decorative textiles. Plush, hand-tufted, 100 percent wool face tapestries are often used on upper panel surfaces. Lightweight carpeting or a grospoint construction is common on lower panel surfaces. A variety of materials and methods are used to make tapestries. The lower surface textile, wainscoting, is usually fabricated of treated wool or nylon with a very lightweight backing or no backing. With the new heat release regulation, most of the previously used tapestries and wainscoting can no longer be applied. Tapestry and wainscoting fabrics made from synthetics and wool/synthetic combinations are produced in order to meet the heat release requirements.

C.4.4.3 Paint

Interior polyurethane and water-based paints are used primarily on surfaces that see little abuse, such as those behind the pilots. Paint is also used on many small parts throughout an aircraft.

C.5 Floor Coverings

The type of floor covering used depends on the location in the aircraft. All floor coverings must meet FAR 25.853(b). Carpet covers most of the cabin floor, including the aisle and under the seats. Most aircraft have wool- or nylon-face yarns with polyester, polypropylene, cotton, or fiberglass backing yarns and a fire-retardant back coating. Wool-face yarns are treated with a fire retardant. Nylon carpets must have a highly fire-retardant back coating for fire resistance. Carpet underlays of felt are used in some aircraft for noise suppression. Areas where fluid spills are likely, such as galleys and lavatories, use plastic floor coverings typically made of vinyl with a reinforcing fabric backing and an antislip surface.

C.6 Draperies

Draperies are used to close off sections of the aircraft such as galleys and to separate the classes of passenger service. Drapery fabrics are usually wool or polyester fabric that has been treated with a flame retardant.

C.7 Nonmetallic Air Ducting

Due to the relative compactness of an aircraft, much of the conditioned air ducting has to be routed around many different parts. This results in some very complex shapes. Nonmetallic ducting is used to create these complex parts because it is much less expensive to fabricate than aluminum ducting. There are three basic types of nonmetallic duct constructions: fiber-reinforced resin, thermoplastic, and rigid foam. All conditioned air ducting must meet FAR 25.853(b).

C.7.1 Fiber Reinforced

Fiber-reinforced resins consist of woven fiberglass with polyester, epoxy, or phenolic resin systems. Some aromatic polyamide/epoxy is also used. Ducts made from these materials are usually coated after curing on the outside with a polyester or epoxy resin to seal against leaks. Fiberglass impregnated with silicone rubber is the industry standard for duct boots because of flexibility, strength, low air permeability, and good fire resistance.

C.7.2 Thermoplastic

Thermoplastic ducting is typically made of vacuum-formed polycarbonate or polyetherimide. Thermoplastic ducts are not as strong as fiber-reinforced resin; however, thermoplastic ducts are much less costly to fabricate.

C.7.3 Foam

Polyimide or polyisocyanurate foam ducts are used for larger ducts with complex shapes and have the advantage of not requiring additional insulation. Foam ducts are popular for their low weight.

C.8 Linings (Nonpanel)

Linings are used where strength and flexibility are required to provide a contoured shape; in addition, linings provide an aesthetically pleasing surface and protect the assemblies behind the liner. Areas such as the exit door, flight deck, cabin sidewalls, door frames, and cargo holds utilize liners fabricated of reinforced resins or thermoplastics. Decorative sidewall liners made of formed aluminum are used in some aircraft. Depending on the application, the liners must meet FAR 25.853(a), (a-1), or (b) or FAR 25.855(a) or (a-1) or a combination.

C.8.1 Reinforced Resin

Linings that are subjected to passenger and food cart traffic are typically manufactured from plies of fabric-reinforced resin. Their flexibility, impact resistance, high strength, and low weight make them ideal for lower sidewall kick panels. Cargo liners required to meet FAR 25.855(a) and (a-1) are fabricated using fiberglass reinforced resins because of the burn-through and impact resistance.

C.8.2 Thermoplastics

Linings that see less abuse and do not require high strength are fabricated from thermoplastics because less expensive fabrication methods are used. Flight deck sidewalls, upper door liners, attendant stations, and closeouts are typical applications for vacuum and pressure formed thermoplastics such as ABS, polycarbonate, and polyetherimide. In many applications, thermoplastics are integrally pigmented and textured and do not require any decorative covering.

C.9 Electrical Components

C.9.1 Wire and Cable Insulation

Wire and cable insulation comprises a substantial amount of the nonmetallic material in an aircraft. For general wire and cable applications inside the pressure shell, the majority of the insulation used is polyimide (Kapton). Not quite as prevalent is irradiated, crosslinked, polyethylenetetrafluoroethylene. In some areas, aromatic polyamide braiding is used to cover power feeder cables for scuff resistance. For higher temperature and fuel areas polytetrafluorothylene (PTFE) is used almost exclusively. Where very high temperature or burn-through resistance is a requirement, filled PTFE is typically used. Asbestos had been used as the filler in the past, but has been replaced by proprietary fibers. To withstand the high temperature requirements of fire zones, heavily nickel-plated copper wire is used to ensure continued operation of electrical equipment. All wire insulations must meet FAR 25.1359(d), and those located in fire zones must also meet FAR 25.1359(b).

C.9.2 Conduit and Tubing

Different types of conduit and tubing are used for electrical wires and components. Polyvinyl fluoride and polyolefin heat shrink tubing, silicone glass fiber braid, and extruded and convoluted nylon tubing are industry standards.

C.9.3 Connectors

Most connectors in an aircraft are made of Bakelite aluminum with silicone or hardened dielectric material inserts and have no specific FAR burn requirements. Connectors located in firewalls, however, must be fireproof and are made of low carbon or stainless steel to meet burnthrough requirements.

C.10 Firewalls

Firewalls are required around all designated fire zones (e.g., engine compressor, accessory sections) to isolate a fire (see figure C-4). Titanium and steel of at least 0.015-inch thickness are used as firewalls. Steel is the preferred material as it does not warp under heat to the extent titanium does. To provide even more burnthrough resistance in specific areas, resin-impregnated high-silica glass or coated niobium is used.

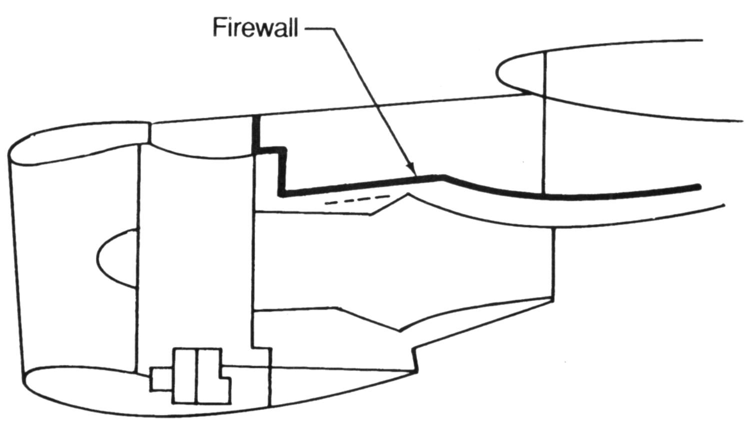


Figure C-4. Typical High Bypass Engine

C.11 Windows

All aircraft windows at present are fabricated from stretched cast polymethylmethacrylate. Stretched acrylic has the optical clarity, strength, low weight, and solvent resistance required. All windows must meet FAR 25.853(b-2).

C.12 Small Parts

Except for electrical wire and cable insulation and for small parts (such as knobs, handles, rollers, fasteners, clips, grommets, rub strips, pulleys, and small electrical parts) that the Administrator finds would not contribute significantly to the propagation of a fire, parts/materials not identified in FAR 25.853(a), (b), (b-1), or (b-2) shall not have a burn rate greater than 4 inches per minute when tested horizontally in accordance with FAR 25.853 (b-3).