FLIGHT SAFETY FOUNDATION
CABIN CREW SAFETY
Vol. 33 No. 2 *For Everyone Concerned with the Safety of Flight* March–April 1999

# Uniform Materials Affect Flight Attendant Safety and Ability to Help Passengers Evacuate Burning Aircraft

***No specific flammability standards exist in the United States for flight attendant uniforms. Clothing-safety specialists said that the best alternatives currently available are pure woolen outer garments treated for fire resistance and undergarments made of natural fibers.***

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The primary duty of a flight attendant is to help passengers evacuate the aircraft in an emergency requiring evacuation. If a flight attendant is incapacitated, that duty cannot be accomplished. In an emergency, particularly one involving fire, the flight attendant's uniform can affect his or her ability to help passengers evacuate an aircraft.

Although smoke and toxic gases usually are the more significant threats in an aircraft fire, the threat of thermal injury (burns) can be increased if a flight attendant is not clothed properly, as shown by the following example:

On June 8, 1995, ValuJet Airlines Flight 597, a Douglas DC-9-32, experienced an uncontained failure of the right engine while departing from William B. Hartsfield Atlanta (Georgia, U.S.) International Airport for a scheduled flight to Miami, Florida, U.S., with 57 passengers and five crewmembers.[1] The aircraft was accelerating during the takeoff roll when the seventh-stage high-speed-compressor disk ruptured. Disk fragments penetrated the fuselage and the right-engine main fuel line.


The U.S. National Transportation Safety Board (NTSB) said, in its accident report, that pressurized fuel entered the cabin and was ignited by sparks that likely were generated by contact between the disk fragments and steel galley components. Fire spread quickly through the cabin.

The captain rejected the takeoff. The aircraft was stopped on the runway, and the occupants evacuated within two minutes.[2] Six occupants sustained minor injuries; one occupant, a flight attendant, was seriously injured. The aircraft was destroyed by fire.

Several passengers told investigators that they heard a bang, looked toward the rear of the cabin and saw the flight attendant in the rear jump seat engulfed in flame. In her statement, the flight attendant said that she was surrounded by fire but did not feel any pain. She was able to release her seat belt and, with the help of passengers, evacuate through the left overwing exit.

The flight attendant's injuries included shrapnel wounds and second-degree burns over 15 percent of her legs. A key

factor in her burn injury was her uniform, which consisted of a short-sleeve polo shirt, shorts, socks and sneakers. The burns were concentrated in areas of her legs that were not covered.

"Had she been wearing attire similar to that recommended in [a 1994 U.S. Federal Aviation Administration (FAA) brochure[3]], she may not have been burned," said the report.

The FAA brochure recommends that, "for ease of movement and protection in the unlikely event of an evacuation, [passengers] should follow these guidelines:

- "Wear clothes made of natural fabrics such as cotton, wool, denim and leather. [These fabrics] offer the best protection. Synthetics may melt when they are heated;
- "Wear clothing that allows freedom of movement. Avoid restrictive clothing;
- "Wear low-heeled shoes or boots. (Shoes with laces or straps are recommended. Avoid sandals.); [and,]
- "Arms and legs should be as fully covered as possible. (Long sleeves/pants are recommended.)"

Based on its investigation of the accident, NTSB recommended that FAA "issue an operations bulletin recommending that principal operations inspectors advise their air carriers to disseminate [FAA] safety guidance on airline-passenger attire to their flight attendants. (A-96-88)."

In response to the recommendation, FAA on Jan. 7, 1997, issued the following information in a flight standards information bulletin to air carriers:

"Safety experts agree that in order to decrease the chance of sustaining burns, it is better to wear long sleeves and pants, than it is to wear short sleeves and short pants. In addition, [natural] fabrics such as wool and cotton are better than synthetic fabrics. Also, it is better to have low-heel shoes which are enclosed, and straps or laces are encouraged while sandals are discouraged."

The bulletin said that air carriers should ensure that crewmembers and those who develop criteria for crewmember attire are aware of this information.

Fire significantly reduces the probability of surviving an aircraft accident. During the past 25 years, approximately 6.5 percent of all aircraft accidents have involved fire.[4] A U.S. General Accounting Office (GAO) report found that approximately 16 percent of all U.S. transport aircraft accidents between 1985 and 1991 involved fire, and that approximately 22 percent of the fatalities from those accidents resulted from the effects of fire and smoke.[5]

"Fire is a major concern because of the large quantities of flammable fuel carried by the aircraft and because of the cabin's design," said the GAO report. "Once interior materials begin to burn, the fire spreads rapidly throughout the aircraft because of its long, narrow interior design.

"Conditions within the aircraft degrade rapidly to the point where life cannot be sustained except possibly at locations close to the floor. If the fire grows, a condition called 'flashover' is reached, when everything within the cabin is burning and survival is impossible." Flashover occurs when combustion products trapped in the upper part of the cabin ignite suddenly.

Rudolf Kapustin, former NTSB accident investigator and president and principal consultant at Intercontinental Aviation Safety Consultants, said, in a 1993 report prepared for *Flight Safety Digest*, "Nearly all aircraft-accident fatalities that are not the result of crash/impact injuries are the result of postcrash fires and the inability to exit aircraft quickly, which in most cases is attributed to incapacitation from toxic smoke, fumes or injuries."[6]

S. Harry Robertson, a specialist in fire survival and CEO of Robertson Aviation, said that, particularly when impact forces are within human tolerance and the fuselage remains intact or partly intact, the ability to evacuate the aircraft becomes the most significant factor in survival.[7]

An NTSB special-investigation report in 1992 said that in emergencies requiring aircraft evacuation, "flight attendants usually provide the most immediate assistance to passengers."[8]

Nevertheless, as of April 1999, no flammability standards or regulations pertaining to flight attendant uniforms exist in the United States, beyond the standards applied to all consumer clothing. (See "U.S. Efforts to Regulate Clothing Flammability Prompted by Injuries, Deaths," page 3; and "FAA Sets Flammability Standards for Cabin Furnishings, but Not for Crewmember Uniforms, page 4.)

Constantine P. Sarkos, Fire Safety Section manager at the FAA William J. Hughes Technical Center, said that in most survivable accidents involving postaccident fires, fire ignited by fuel from external tanks ignites the cabin, jeopardizing the evacuation of the occupants.[9]

In the early phases of a cabin fire, a distinct layer of smoke and gases forms near the ceiling and spreads horizontally. The air below the smoke layer remains cooler and relatively clear. As doors and hatches are opened for egress, fresh air flows into the cabin; flames might spread rapidly throughout the interior, reducing chances of survival for occupants who have not evacuated.

In accidents where the fuselage is broken open, the fire can penetrate much faster and spread more quickly through the

## U.S. Efforts to Regulate Clothing Flammability Prompted by Injuries, Deaths

The first attempt to regulate flammability of consumer clothing in the United States was the Flammable Fabrics Act of 1953. Before this legislation was adopted, there was no control, beyond self-regulation by the clothing industry, of the materials used in clothing. The legislation resulted from injuries and deaths caused when clothing ignited, and was intended to ban the sale of clothing considered extremely flammable.

The Flammable Fabrics Act has been amended several times. In 1967, an amendment added standards for flammability testing and for rating fabrics and materials on their flammability characteristics. In 1972, again as a result of injuries and deaths caused by burns produced by clothing articles, flammability standards for children's sleepwear were enacted.[1]

Since 1972, the U.S. Consumer Product Safety Commission has established a series of standards for testing and classification of clothing based on design and flammability characteristics.

The standards are in 16 U.S. Code of Federal Regulations Part 1610*: Standard for the Flammability of Clothing Textiles.* These regulations require that textiles be tested according to specified procedures for ease of ignition and flame-spread rate (i.e., the time required for the flame to travel five inches [13 centimeters]).

Part 1610 assumes that most textiles are combustible and that, when used for clothing, are potentially hazardous to the wearer. The required testing exposes several textile specimens, each measuring two inches by six inches (five centimeters by 15 centimeters) to a small flame for one second, while oriented at a 45-degree angle to the flame. The textile then is classified by the following criteria:

- Class I Materials (normal flammability) — Textiles without a raised-fiber surface that have flame-spread rates of four seconds or more; or textiles with raised fibers that have flame-spread rates of more than seven seconds or burn with a rapid surface flash without igniting or fusing the basic fabric. Part 1610 said, "Textiles meeting these requirements are generally accepted by the trade as having no unusual burning characteristics";

- Class II Materials (intermediate flammability) — Textiles with a raised-fiber surface that have flame-spread rates of four seconds to seven seconds and the base fabric ignites or fuses. Part 1610 said, "Textiles meeting these requirements are recognized by the trade as having flammability characteristics between normal [burning] and rapid-and-intense burning"; and,

- Class III Materials (rapid-and-intense burning) — Textiles that have flame-spread rates of less than four seconds. Part 1610 said, "Such textiles are considered dangerously flammable and [are] recognized by the trade as being unsuitable for clothing."

Use of Class III textiles in general wearing apparel is prohibited.♦

— William D. Waldock

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1. Marcy, J.F.; Nicholas, Eldon. *Data Report No. 96 — Flammability of Airline Stewardess Uniform Fabrics*. Project no. 184-732-05X. A report prepared for U.S. Federal Aviation Administration National Aviation Facilities Experimental Center. August 1972.

cabin because the air flow usually is much more turbulent. Rapid evacuation is the only way to save the occupants.

Burn injuries are caused by radiant heat and by ambient heat. Aircraft fires typically produce high radiant heat. Radiant heat is transferred by radiation in a line-of-sight path from the fire to the victim. Protection from radiant heat is achieved by placing a barrier between the fire and the victim's skin. Almost any type of barrier will be sufficient; clothing might provide a barrier for a limited time in some situations.

Ambient heat is transferred from the fire to the cabin environment and occupants by a combination of conduction and convection. For a victim exposed to ambient heat, the type and quantity of clothing worn is the first line of defense. Covering the skin and providing some degree of insulation are necessary to protect against burns. A single garment, by itself, provides no protection from ambient heat; as the fabric is heated, the heat is transferred through the material to the skin, resulting in a burn.

Some military aviators have been burned through their Nomex flight suits, because they were not wearing undergarments or were not wearing undergarments made of suitable fabrics. Materials such as Nomex do not, by themselves, give the wearer adequate protection. Nomex can withstand heat up to 800 degrees Fahrenheit (427 degrees Celsius) before decomposing; nevertheless, if the material is next to the skin, the heat is transferred through the Nomex to the skin. Insulation provided by undergarments made of 100 percent natural fibers can reduce the amount of heat that is transferred.

Materials and fabrics have been tested in many different fire situations and environments. (See "Tests Show Fabric Flammability Characteristics," page 5.) The most important

*continued on page 6*

## FAA Sets Flammability Standards for Cabin Furnishings, But Not for Crewmember Uniforms

The U.S. Federal Aviation Administration (FAA) has established flammability standards for aircraft-cabin furnishings. Although FAA in 1978 proposed establishing flammability standards for crewmember uniforms, it later determined that accident/incident data and public comment on the proposal did not support further rule making.

Recognizing that clothing could affect the ability of flight attendants to perform vital tasks in an emergency involving fire, FAA in 1966 conducted uniform-fabric flammability tests at the National Aviation Facilities Experimental Center (now the William J. Hughes Technical Center) in Atlantic City, New Jersey, U.S.

FAA tested two uniform-fabric samples provided by a major U.S. airline. One sample was from a summer uniform and was made of 46 percent Dacron polyester (synthetic fiber), 23 percent wool and 21 percent mohair; the other sample was from a winter uniform and was made of 100 percent wool. The test report said that both fabrics met the clothing flammability standards then in effect. Nevertheless, the report said that the polyester/wool blend showed a tendency to melt and drip, and that both fabrics failed to self-extinguish during vertical burn tests. The report recommended development of fabrics with more fire resistance.[1]

In response to information from the Association of Flight Attendants (AFA) that some items of flight attendant clothing were highly flammable when exposed to an ignition source, FAA in 1975 issued an advance notice of proposed rule making (ANPRM) soliciting comments and information to assist in developing flammability standards for flight attendant uniforms.[2]

FAA received 33 public comments from research organizations, manufacturers and aviation organizations. The comments generally agreed that fire-resistant fabrics were available, but disagreed on fabric durability after treatment, comfort under various climate conditions, and adaptability to styling and tailoring. Several comments cited the necessity to clearly define the fire hazards that flight attendants are likely to encounter in the performance of their duties.[3]

FAA in 1978 issued a notice of proposed rule making (NPRM) on flammability standards for flight attendant uniforms.[4] The NPRM said that because many items of uniform clothing were highly flammable when exposed to flame and other ignition sources, these items might not withstand the thermal effects (flame and heat) of otherwise survivable aircraft fires and could prevent flight attendants from assisting passengers. The NPRM said that there were four alternatives for flight attendant uniform flammability standards:

- "Do not require uniforms worn by crewmembers to meet any flammability standard. Although current uniform materials provide maximum comfort, range of styling and cleanability, at present they are constructed of conventional fabric that may be ignited or may provide inadequate protection from radiant heat in survivable cabin fires. Without protective clothing, crewmembers may be incapable of performing necessary functions in certain emergencies;

- "Require crewmember[s] to put on special fireman-type garments in case of a fire. [Although such garments provide] maximum protection from flame and radiant heat, [they are] very expensive and difficult to put on;

- "Require crewmember uniforms to meet a standard similar to the current [U.S.] children's sleepwear standards. This is a performance standard that requires materials used for children's sleepwear to resist ignition when exposed to flame and to self-extinguish rapidly. Materials which satisfy the children's sleepwear standard must be flame-resistant, but need not protect the wearer from radiant heat transferred through clothing; [and,]

- "Require crewmember uniforms to meet an ignition-resistance and self-extinguishment test as well as a standard designed to protect the wearer from injury from the transfer of radiant heat through the clothing."

The NPRM said that the latter alternative was the most desirable. "Currently, technology in the textile industry permits the establishment of a standard that protects wearers from both flame and radiant heat," the NPRM said. "Most fabrics can be treated to increase their protective qualities. In addition, fire-retardant wool and cotton are available in a wide range of colors and weights."

FAA held a public hearing on the NPRM in 1980. Presentations were made by FAA; AFA; the Air Line Pilots Association, International (ALPA); the American Textile Manufacturers Institute; the National Air Transportation Association; and the National Cotton Council. AFA and ALPA recommended adoption of flammability standards for flight attendant uniforms. Several other participants said that there were no data on accident injuries and fatalities to show an unsafe situation requiring correction.[5]

The NPRM was withdrawn in 1981. "There is no proof that aviation-safety regulations are needed in this area," FAA said. "There remains no clear definition of the fire hazard to be met [and] no verifiable data on injuries or death due to flammable uniforms … . In addition, flight attendant unions [that] surveyed their members found that a majority of those responding are not willing to sacrifice style, comfort or cleanability to obtain uniforms of higher flame resistance."[6]♦

— William D. Waldock

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## Tests Show Fabric Flammability Characteristics

Embry-Riddle Aeronautical University in February 1997 conducted a series of tests to determine the characteristics of certain fabrics when exposed to heat and the time required for consumption of the fabrics by fire.

The tests, conducted as part of the university's Aircraft Crash Survival Investigation course, used five-inch-square (13-centimeter-square) samples of common clothing fabrics. The samples were suspended over an alcohol burner so that the flame contacted only the lower edge of the fabric; the flame was removed after the fabric began to burn.

Two tests were conducted for each fabric, and the recorded consumption times were averaged. Table 1 shows the results of the tests.[1]♦

— William D. Waldock

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### Table 1
### Characteristics of Common Clothing Samples When Exposed to Fire

| Fabric Sample | Characteristics | Consumption Time[a] |
|---|---|---|
| 100% cotton jacket | Burned, charred | 24 seconds |
| 100% cotton sweatshirt | Burned, charred | 33 seconds |
| 60% polyester/40% wool trousers | Melted, ignited | 21 seconds |
| 70% polyester/30% cotton shirt | Melted, dripped, ignited | 14 seconds |
| 100% cotton trousers (thick) | Charred, decomposed | 75 seconds |
| 100% cotton trousers (thin) | Charred, decomposed | 35 seconds |
| 100% flannel shirt | Ignited, charred | 19 seconds |
| 100% Dacron blouse | Burned, melted, dripped | 24 seconds |
| Nylon pantyhose | Burned, melted[b] | 48 seconds |
| Fire-resistant pajamas | Burned, melted[b] | 66 seconds |
| Nomex III undershirt[d] | Local charring only | [c] |

[a] Time between removal of flame and complete fire consumption of sample.

[b] Burning stopped and melting stopped when flame was removed.

[c] Did not burn; test was stopped after 180 seconds.

[d] Nomex III is a variant of Nomex.

Source: William D. Waldock, Embry-Riddle Aeronautical University Burn Tests, 1997

factors in the level of fire protection provided to the wearer are the fabric's ignitability, self-extinguishing characteristics and structural characteristics when exposed to heat. These factors are affected by the fabric's weave, the size of the fibers in the weave, the density of the weave and the thickness of the material.

How a fabric burns when ignited can affect what happens to the wearer. Sally Hasselbrack, Ph.D., senior technical fellow at The Boeing Co. and a specialist on fabric flammability, said that most synthetics shrink before they melt; some fuse into molten globs; and some drip burning globs on anything underneath them.[10]

Tests conducted for FAA showed that fabrics made of polyester, vinyl, rayon and various blends of polyester with wool and cotton are highly flammable.[11] In some tests, materials worn under other garments melted due to heat conducted through the outer fabric. The polyester/wool and polyester/cotton blends were found to have flammability characteristics similar to those of polyester alone.

Hasselbrack said that all the current, non-fire-treated synthetic materials used in crewmember clothing exhibit flammability characteristics that would result in injury or incapacitation to the wearer, if they are exposed to fire.[10]

Air Canada requires fabrics to be tested for fire resistance before they are approved for use in uniforms. Barbara Dunn, a senior flight attendant for Air Canada, said that the recommended uniform, as of February 1999, was a 100 percent woolen jacket and trousers or skirt.[12]

There are several factors to consider when evaluating fabrics and clothing for uniforms that flight attendants will wear daily and in a variety of work situations and settings. (See "Lack of Awareness of Fire Hazards Precludes Uniforms that Better Protect Flight Attendants," and "Unions Seek Protection for Flight Attendants, Pilots," page 7.) The most important factors to consider are:[10, 13]

- Comfort — The feel of the fabric, its ability to absorb water or draw water away from the skin, breathability, stiffness, and any tendency to irritate skin;
- Launderability and maintenance — The ease with which the clothing can be cleaned, how it deteriorates with cleaning, and the effects of cleaning processes on fire-retardant characteristics;
- Durability — How well the fabric and clothing stand up to environmental and mechanical stresses;
- Reaction to fire — The characteristics of the fabric when exposed to heat and/or flame; and,
- Protection — The ability of the fabric to protect the wearer from fire, including how the fabric conducts heat, the temperatures at which its structure changes, and whether it self-extinguishes after ignition.

Compromises are involved in flight attendant uniform selection. Although a shell of polybenzimidazole (PBI, an organic fiber that does not burn or melt) with layers of Nomex and thick insulation underneath (combining features of a firefighter's "proximity" suit with a military flight suit) would

## Lack of Awareness of Fire Hazards Precludes Uniforms that Better Protect Flight Attendants

A 1997 survey of safety personnel and operational personnel at eight U.S. carriers and one Canadian carrier found that most regulations pertaining to flight attendant uniforms remain essentially unchanged since the 1960s.[1]

In the survey, one carrier said that its flight attendant operations manual requires that, in an emergency involving imminent threat of fire, flight attendants remove hosiery and dampen their hair if they had used hair spray.

Polyester/cotton blends and polyester/wool blends commonly are used in flight attendant uniforms. Although these fabrics generally are easy to maintain and do not wrinkle readily, they ignite relatively quickly, shrink, melt and continue burning after the heat source is removed.

Flight attendants might be called upon to try to control a small fire with fire extinguishers or during evacuation of the cabin, flight attendants will be required to remain in the cabin until all the passengers have exited or until the environment in the cabin becomes too hazardous. A flight attendant fully clothed in fire-resistant fabrics will have more endurance in such situations than a flight attendant attired in shorts or a skirt, or in clothing made from materials that conduct heat, melt or ignite.

Almost every female flight attendant's uniform includes nylon stockings or pantyhose, and there have been incidents in which these clothing items contributed to injuries during aircraft evacuations. When a flight attendant must evacuate on a slide, her hosiery can be melted by the heat of friction from contact with the slide; this can cause burn injuries.[2]♦

— William D. Waldock

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## Unions Seek Protection for Flight Attendants, Pilots

The Association of Flight Attendants (AFA), in contract negotiations with air carriers, seeks agreements that fabrics used in flight attendant uniforms be required, at the minimum, to meet the Class I material standards of 16 U.S. Code of Federal Regulations Part 1610: *Standard for the Flammability of Clothing Textiles*.[1]

The regulations define Class I materials as those having normal flammability characteristics. (See "U.S. Efforts to Regulate Clothing Flammability Prompted by Injuries, Deaths," page 3.)

AFA, which represents approximately 44,000 flight attendants employed by 23 U.S. air carriers, also seeks agreement from air carriers that flammability tests will be conducted on any new items considered for flight attendant uniforms.

Flight-crew-uniform recommendations are included in an accident-survival guide prepared by the Air Line Pilots Association, International (ALPA) for the 53,000 pilots it represents at 52 airlines in the United States and Canada. The ALPA guide provides the following information:[2]

"To reduce the incidence of aircrew injury or incapacitation by burns, flame [-retardant materials] and radiant-heat-retardant materials should be utilized in the manufacture of aircrew uniforms. Because of their tendency to melt in relative[ly] low levels of radiant heat, synthetic polyester fibers are not, at present, suitable for use in aircrew uniforms, except when used as a mixture with cotton and wool. Only when crewmembers and airlines encourage the development of flame-retardant materials, will flame-retardant uniforms become available.

"At present, prevention or minimization of fire burn injuries can best be accomplished by:

- "Selecting tightly woven, natural-fiber materials such as gabardines;
- "Avoiding use of high-polyester-content garments; and,
- "Wearing long-sleeved shirts, blouses or coats.

"Aircraft crewmembers should be encouraged to own and maintain Nomex gloves (for use as hand protection from flame or heated-material aircraft parts) that are accessible during flight. Since quick-don-style hoods provide valuable protection from heat and smoke, and thus allow crewmembers supervising emergency evacuation some additional time to direct escape from a postcrash fire, it is recommended that such coverings … be provided to crewmembers."♦

— William D. Waldock

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provide a high level of protection from fire, a uniform made this way would not be practical for use by flight attendants. Therefore, practical alternatives should be pursued.

Some currently available alternatives include the following:

- A uniform jacket and trousers made of 100 percent wool treated for fire resistance;
- A blouse or shirt made of natural fibers, such as cotton or wool;
- Undergarments made of natural fibers; and,
- Low-heeled or flat shoes with closed toes.

Flight attendants should avoid leaving large areas of the body uncovered, and should avoid wearing fabrics made of synthetic fibers (including blends), wigs and hairpieces made of synthetic materials, and ties or scarves made of synthetics.♦

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